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THE OSTEOLOGY AND PHYLOGENETIC RELATIONSHIPS OF THE BLACKFIN TUNA, *THUNNUS ATLANTICUS* (LESSON)[1]

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ABSTRACT

Comparisons with five other species of the genus *Thunnus* were made to determine the relationships and phylogenetic position of *T. atlanticus* and its correct taxonomic identity. From osteological evidence, *T. atlanticus* is intermediate with *T. sibi* and *T. albacares* and is slightly closer to the latter. The splitting of the genus *Thunnus* as proposed in the past by various authors is osteologically unsubstantiated in view of the compactness of the group formed by the six species of *Thunnus* and their closer relationships to each other than to any of the neighboring genera (*Katsuwonus, Euthynnus, Sarda*) with which *Thunnus* was compared. It is therefore suggested that the names *Parathunnus, Neothunnus* and *Germo* be incorporated with the genus *Thunnus*.

INTRODUCTION

In the commercial exploitation of any organism it is necessary to know the identity and taxonomic relations of the species involved for the rational management and utilization of existing stocks. In this respect, while the tuna fisheries of the world rank high in importance and in time and effort expended in their exploitation, little has actually been learned about the life histories of the tunas. The blackfin tuna, *Thunnus atlanticus* (Lesson), is known only from the tropical western Atlantic, occasionally as far north as Cape Cod (Mather and Schuck, 1952: 267) and south to Brazil (Beebe and Tee-Van, 1936: 178). A commercial fishery for this species exists off Cuba (Rawlings, 1953), and the possibility of establishing a fishery in the Caribbean is now being investigated. Moreover, large numbers of these tuna are caught at certain times of the year by sports fishermen in the south Florida area and are highly esteemed for their sporting qualities.

[1]Contribution No. 140 from the Marine Laboratory, University of Miami.

In view of its increasing importance, a study of the hitherto unknown life history of the blackfin tuna should be undertaken. As a basic step toward knowledge of its systematic position, and future population and racial studies throughout its range, the present study has been conducted. Kishinouye (1923), Starks (1910), Godsil and Byers (1944) and Nakamura (1952) have described and discussed in detail the osteology of several species of the family Scombridae. However, partly due to the general confinement of these studies to Pacific forms and also to its confusion with the albacore, *Thunnus alalunga* (Rivas, 1951: 219), no osteological studies have been conducted on the blackfin tuna. It is the purpose of this work to present a detailed osteological study of the blackfin tuna and to derive therefrom the phylogenetic relationships and taxonomic position of the species.

The author wishes to express his gratitude to Luis Rene Rivas for his guidance during the course of this study. The assistance of Julian D. Corrington, H. F. Strohecker and W. Henry Leigh is acknowledged for reading the manuscript critically. Thanks are also due to H. C. Godsil of the California Department of Fish and Game for the loan of osteological material, to the author's wife for assistance in the collection and preparation of the material, to Donald F. Menker of the Marine Laboratory of the University of Miami for assistance with the photography, and especially to the fishing boat captains of Pier 5, Miami and the Chamber of Commerce Docks, Miami Beach, for the procurement of specimens used in this study.

Materials and Methods

In addition to the specimens of blackfin tuna collected off Miami, two specimens of the Pacific bigeye tuna *(Thunnus sibi),* two albacore (*Thunnus alalunga*) and one bluefin tuna (*Thunnus thynnus*) were loaned to the author by H. C. Godsil of the California Department of Fish and Game. Two specimens of yellowfin tuna *(Thunnus albacares),* one bonito (*Sarda orientalis*) and one cero mackerel (*Scomberomorus regalis)* were collected at Bimini, Bahamas and at Pinas Bay in Panama by Luis R. Rivas. The remaining specimens used, the frigate mackerel *(Auxis thazard),* the arctic bonito *(Katsuwonus pelamis)* and the little tuna (*Euthynnus alletteratus*) were all collected off Miami Beach. A total of 29 specimens of blackfin tuna, 273 to 718 mm in fork length, were used. The largest specimen weighed 17 pounds, and although the species has been reported by Mowbray (1935) as reaching 60 pounds, it probably does not exceed 25 or 30.

The genus *Thunnus* shows very little individual and ontogenetic variation within species. Owing to this, the author has felt justified in using a smaller number of specimens than would be required for taxonomic work.

The nomenclature and abbreviations for the cranial bones and pectoral girdle used in this study are those of Gregory (1933) with the exception of certain changes and additions marked by asterisks. Those of the vertebral column and appendages are of Atwood (1947), Hyman (1942) and Stokely (1952: 255-261).

Skeletons were prepared for study by boiling with solutions of commercial detergents followed by bleaching in 10% hydrogen peroxide. In order to isolate certain bones, partial boiling was necessary to assist separation from the tough skin. The delicate structure of certain bones (i.e., finlets, fin rays and scalation pattern) precluded the boiling of these parts and staining techniques of alizarin red S and potassium hydroxide were employed following the procedure of Uhler (1952).

The drawings were made from fresh and stained material and represent a composite of 29 specimens.

Classification, Nomenclature and Abbreviations of Osteological Characters

I. SYNCRANIUM
(a) Neurocranium
1. Olfactory region
deth—dermethmoid
pareth—parethmoid
na—nasal
vo—vomer
2. Orbital region
scl*—sclerotic bones
la—lachrymal
so_2—second suborbital
so_3—third suborbital
alsph—"alisphenoid"
fr—frontal
3. Otic region
pa—parietal
pto—pterotic
sphot—sphenotic
epiot—epiotic
soc—supraoccipital
exo—exoccipital
prot—prootic
ptm—posttemporal
stm*—supratemporal
opo—opisthotic
4. Basicranial region
pas—parasphenoid
boc—basioccipital
bas—basisphenoid
(b) Branchiocranium
1. Oromandibular region
pmx—premaxillary
smx—supramaxillary
max—maxillary
pal—palatine
mtp—metapterygoid
ptr—ectopterygoid
enpt—entopterygoid
qu—quadrate
art—articular

an—angular
dn—dentary
2. Hyoid region
hyom—hyomandibular
op—opercle
pop—preopercle
iop—interopercle
sop—subopercle
sym—symplectic
ihy—interhyal
ephy—epihyal
cerhy—ceratohyal
bshy—basihyal
gloss—glossohyal
urohy—urohyal
brstg—branchiostegal
3. Branchial region
pharyngobranchials 1, 2, 3, 4 (last are "upper pharyngeal" bones)
epibranchials 1, 2, 3, 4
ceratobranchials 1, 2, 3, 4, 5 (last are "lower pharyngeal" bones)
hypobranchials 1, 2, 3, 4
basibranchials 1, 2, 3

II. VERTEBRAL COLUMN
(a) Abdominal vertebrae
(b) Caudal vertebrae
(c) Hypural complex

III. GIRDLES AND FINS
(a) Pectoral girdle
cor—coracoid
scap—scapula
cleith—cleithrum
pcl 1—postcleithrum 1
pcl 2—postcleithrum 2
supcl—supracleithrum
ptm—posttemporal
ptryg—pterygials
rays
(b) Pelvic girdle
basipterygia
rays
(c) First dorsal fin
spines
interneurals (pterygiophores—ptg)
(d) Second dorsal fin and finlets
rays
interneurals
(e) Anal fin and finlets
rays
interhaemals
(f) Caudal fin rays

Syncranium

Neurocranium

The neurocranium of *Thunnus atlanticus* (figs. 1-3) is roughly triangular in shape when viewed dorsally, and the sutures are in general strong and rigid. There are three conspicuous foramina, two of which are symmetrically located on either side of the supraoccipital. The third is medially situated immediately in front of the supraoccipital crest.

The most anterior bone of the neurocranium is the median, unpaired *dermethmoid* (deth, fig. 11) which is flat and smooth posterodorsally, but roughened and porous ventrally and posteriorly where it articulates with the vomer and parethmoids respectively. The *parethmoids* (pareth, figs. 1, 2, 3, 4, 7, 12) are paired, massive irregular bones which are very porous on their inner surface. They form the anterior wall of the orbital cavity and are penetrated by the olfactory foramina. Anteriorly, the parethmoids articulate with the dermethmoid, and ventrally there are two processes, the anteriormost joining

FIG. 1

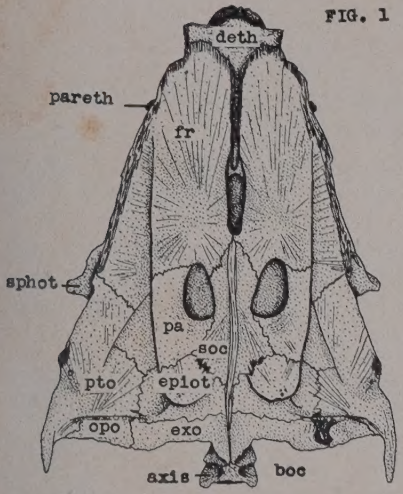


FIG. 2

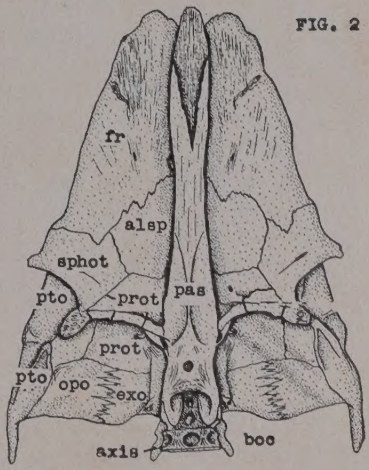


FIG. 3

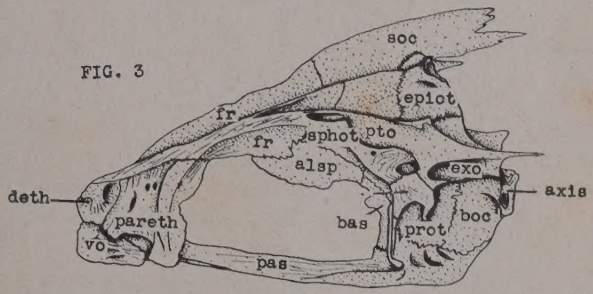


FIGURE 1, Neurocranium, dorsal view; FIGURE 2, Neurocranium, ventral view; dermethmoid, parethmoid and vomer removed; FIGURE 3, Neurocranium, lateral view.

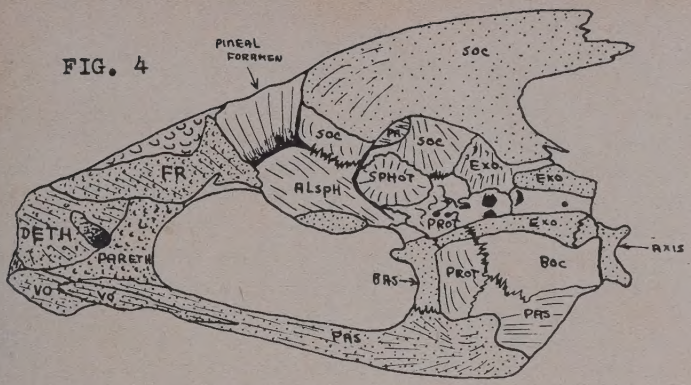
with the vomer while the posterior process serves as an articulating surface for the lachrymal and entopterygoid bones. Ventrally, the parethmoids are connected to the *vomer* (figs. 3, 4, 8) which is an elongate club-shaped bone bearing fine villiform teeth on its thickened antero-ventral surface and tapering posteriorly to overlap and form a solid suture with the parasphenoid (pas).

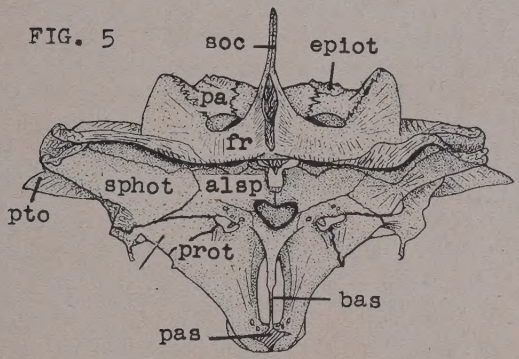
Overlapping the postero-dorsal portion of the dermethmoid two

large dorsally concave *frontal* bones (fr, figs. 1, 3, 4, 5) approximate medially to form a longitudinal groove merging posteriorly into the pineal foramen (figs. 1, 2; Rivas, 1954) which in life is closed in with cartilage. While the frontals are thin bones medially, they become greatly thickened laterally where they form the roof of the orbit. Posteriorly the frontals unite with the pterotic (pto), the sphenotic (sphot) and the parietal dorsally, and with the sphenotic and alisphenoid (alsph) ventrally. The thin, rhomboidal *parietal* bones (pa), posterior to and confluent with the frontals are perforated by the large parietal foramina. The parietals articulate with the epiotics posteriorly, the pterotics laterally, the sphenotics basally and the supraoccipital medially.

Posterior to the pineal foramen the *supraoccipital* (soc, figs. 1, 3, 4) extends upward and posteriorly as a thin, elongate crest (supraoccipital crest) and articulates basally with the parietal, the epiotic, the sphenotic, the prootic and (internally and medially) the alisphenoid. The *epiotics* (epiot) are massive, irregular structures which support the inner process of the *posttemporal* bone (ptm, fig. 32). These are latero-basally connected to the pterotic bones and postero-basally to the exoccipitals (exo). The pterotic is a rather thin bone anteriorly but becomes fairly thick at its articulation with the exoccipital and epiotic and is produced posteriorly as an elongate process characteristic of many of the family Scombridae. Ventrally there are two fossae for the dorsal and anterior condyles of the hyomandibular (fig. 21), and a deep lateral depression separates the pterotic from the sphenotic (sphot). The latter bone forms the posterior part of the orbital roof. Its lateral projection serves for the attachment of the outer process of the supratemporal (stm, figs. 7, 20).

On the inner surface of the sphenotics, the paired *alisphenoids* (alsph, figs. 1, 3, 4, 5) are united by a suture and connect anteriorly with the base of the frontals. A small anterior and a larger posterior foramen occupy the median suture between the paired bones; the posterior margin of the posterior foramen is formed by the upper portion of the median *basisphenoid* (bas). This is a Y-shaped structure, the basal part of which extends ventrally as a straight elongate projection bearing an antero-dorsal basisphenoidal process and basally meeting the median dorsal process of the parasphenoid. The posterior end of the alisphenoid and the upper portion of the basisphenoid unite to meet the frontal portion of an irregular, twisted bone, the *prootic*





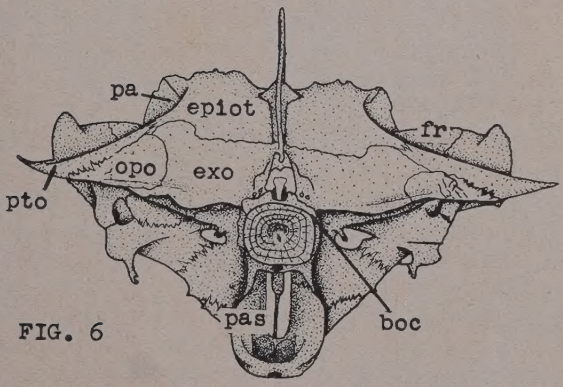


FIGURE 4, Neurocranium, median sagittal section; FIGURE 5, Neurocranium, anterior view: dermethmoid, parethmoid and vomer removed; FIGURE 6, Neurocranium, posterior view.

(prot, figs. 1, 2, 3, 4, 5, 6) which connects basally with the lateral wings of the parasphenoid and posteriorly with the basioccipital. The prootic extends dorsally to form a deep concavity at the suture between the sphenotic and pterotic bones and postero-dorsally connects with a small thin bone, the *opisthotic* (opo) which bears a protuberance on its dorsal surface for articulation with the lateral process of the posttemporal (ptm, fig. 32). The opisthotic is connected laterally to the pterotic and medio-laterally to the exoccipitals (exo) which turn sharply upward on their median suture to form a crest enclosing the foramen magnum. Their posterior surface serves as a recess for the *atlas* (figs. 6, 41) which is detached basally from the ankylosed *axis* (figs. 1, 2). This first vertebra is fused dorsally to the basal condyles of the exoccipitals and anteriorly with the posterior edge of the basioccipital which flares out antero-ventrally as two concave wings which with the parasphenoid form an intervening passage, the myodome, in which the rectus muscles of the eye are located.

Dorsally the basioccipital is connected to the exoccipitals, anteriorly to the prootics, and ventrally to the postero-dorsal articulations of the *parasphenoid* (pas, figs. 1, 3, 4, 5, 6), a long, blade-shaped bone, anteriorly triangular in cross-section with its base concave (fig. 57) and forming the greater part of the ventral surface of the skull. Posteriorly, the dorsal wings articulate with the posteroventral wings of the basioccipital. Ventrally, the junction of these wings forms a rounded protuberance which serves as an attachment for the suspensory pharyngeal bones (fig. 40).

Slightly anterior to this surface two lateral processes extend dorsolaterally to connect with the prootics and a median process articulates dorsally with the basisphenoid. The parasphenoid extends anteriorly where it firmly clasps the posterior portion of the vomer and antero-dorsally articulates with the median basal surfaces of the parethmoids.

In the olfactory region of the skull the *nasals* (na, figs. 7, 9) are lanceolate and thickened anteriorly at their postero-dorsal junction with the premaxillary (pmx). Ventrally they bridge the dermethmoid and taper back to their junction with the anteriormost portion of the frontal bone. The *premaxillaries* (pmx, figs. 7, 14) are a pair of stout curved bones which are united anteriorly by a symphysis forming the cutting edge of the upper jaw. On the ventral surface, each has a single row of strong, inwardly curving teeth which extends the total length of each bone. While the posterior portion becomes attenuated,

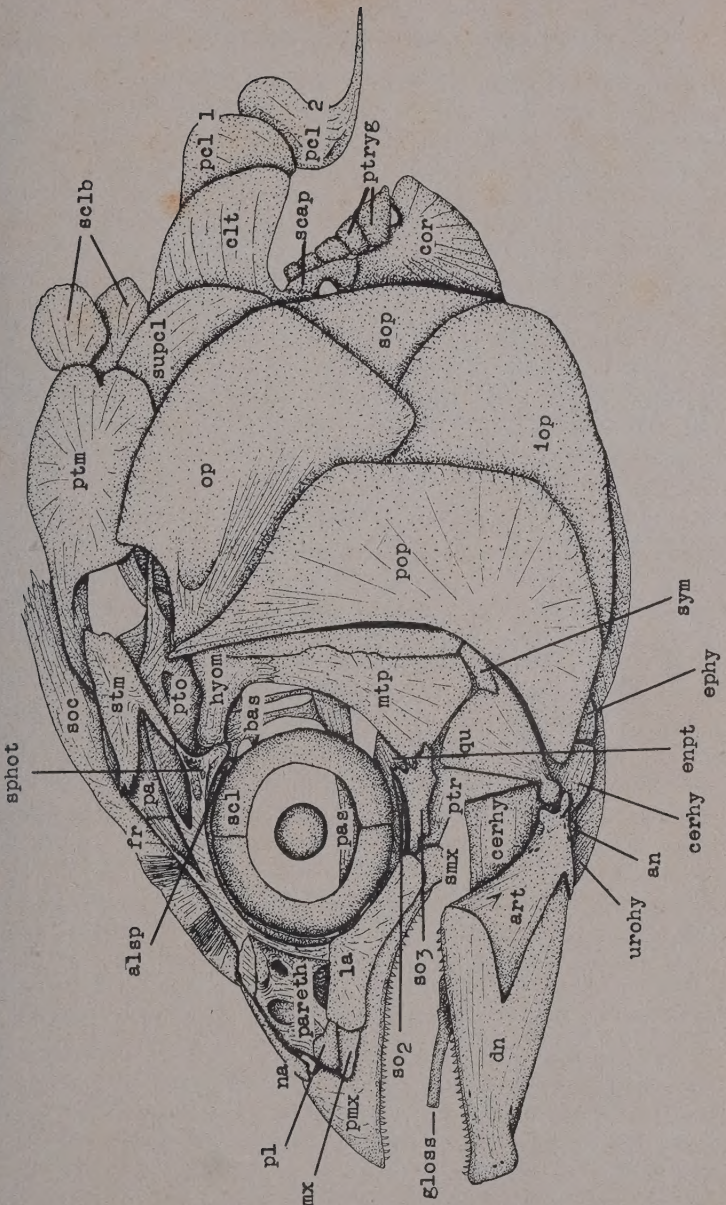


FIGURE 7, Syncranium.

the anterior part is thickened into a massive, upright process, the posterior portion of which is doubly indented to receive two articulating surfaces of the overlaying *maxillary* (max, figs. 7, 15). The maxillary is similar in contour to the premaxillary but bears no teeth. Two irregularly shaped condyles on its anterior surface serve as articulations for the premaxillary. Several fossae penetrate between these condyles, and a deep sulcus is formed on the ventral surface of its longitudinal axis. On the outer surface of the maxillary is a shallow depression to receive the anterior articulating process of the *palatine* (pal, figs. 7, 13). This is an irregular, roughly triangular bone on which a slender ventral extension forms a pedicel which bears an oval patch of fine villiform teeth, this shape being characteristic of *Thunnus atlanticus*. When viewed laterally, the antero-dorsal articulation and an antero-basal portion curve broadly together to form a crescent which loosely clasps the maxillary.

Overlapping the anterior union of the maxillary, premaxillary and palatine is a very thin, flat bone, the *lachrymal* (la, figs. 7, 10) or first suborbital bone. Its dorsal projection unites with the lateral articulation of the parethmoid (fig. 12) and the posterior portion covers the basal part of the sclerotic bones and several thin, flat bones lying ventrally to the orbit, the *suborbitals 2 and 3* (so_2, so_3, fig. 7). Partly occluded by the lachrymal and attached to the posterior part of the maxillary, the *supramaxillary* (smx, figs. 7, 17) is a slightly concave, thin bone with an anterior process for articulation along the dorsal surface of the posterior portion of the maxillary.

The *sclerotic* bones (scl, figs. 7, 29) consist of two thickened semicircular segments joined together to form a heavy shield for the eye. Their outline is elliptical rather than round, a characteristic typical of most of the Scombridae. While the lens does not constitute part of the skeletal system as such, it is included because of its osseous nature. It is composed of a gelatinous substance in life which hardens into a scleroid material upon desiccation. A section through the lens reveals a laminate structure of concentric layers similar to the composition of an onion.

The palatine bone extends posteriorly from its maxillary articulation and is firmly joined to two bones, an outer *ectopterygoid* (ptr, fig. 19) and an inner entopterygoid. The former is a thin, twisted T-shaped bone which is solidly connected to the entopterygoid dorsally and to the quadrate and metapterygoid posteriorly. Inside and at right

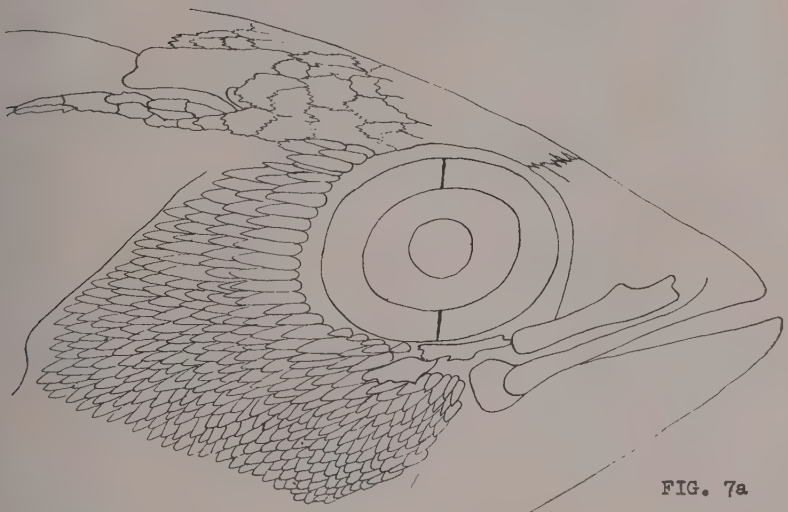


FIG. 7a

FIG. 8

FIG. 9

FIG. 10

FIGURE 7a, Lateral view showing scalation; FIGURE 8, Vomer; FIGURE 9, Nasal; FIGURE 10, Lachrymal.

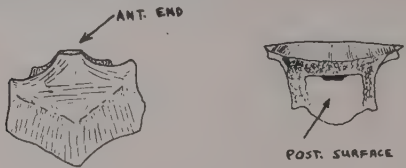


FIG. 11

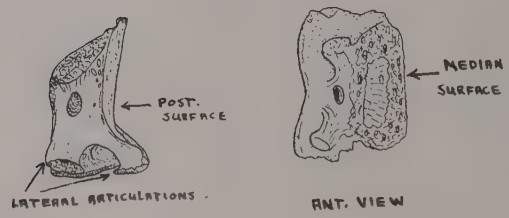


FIG. 12

FIG. 13

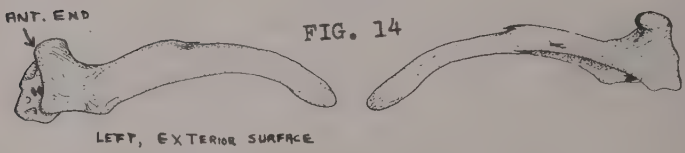


FIG. 14

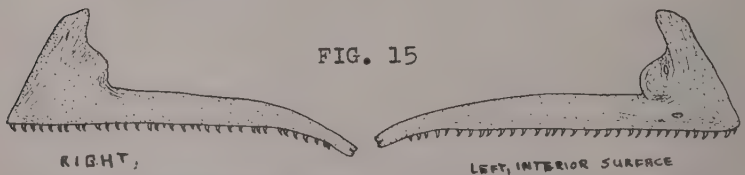


FIG. 15

FIGURE 11, Dermethmoid; FIGURE 12, Parethmoid; FIGURE 13, Palatine; FIGURE 14, Maxillary; FIGURE 15, Premaxillary.

angles to the horizontal axis of the ectopterygoid is a thin, slightly concave, roughly elliptical bone, the *entopterygoid* (enpt. fig. 20) which

forms the floor of the optic cavity and the roof of the oral cavity and is bordered medially by the parasphenoid. It bears a patch of fine villiform teeth on its ventral surface but the texture and extent vary considerably among specimens, and in several cases was completely absent.

The entopterygoid posteriorly borders a somewhat rectangular bone, the *metapterygoid* (mtp, figs. 7, 22). This is thin and flattened and bears five sutures; the dorsal receives the hyomandibular (hyom) and the antero-ventral portion joins the pterygoid (enpt). The ventral surface is in contact with the quadrate (qu) and the postero-ventral suture articulates with the symplectic (sym). The *quadrate* (figs. 7, 24) is a roughly triangular bone which is thin over most of its upper portion. A posterior spinous process serves as an articulating surface for a thin xiphoid bone, the *symplectic* (figs. 7, 23) which bears a stout dorsal process for the articulation with the hyomandibular. The spinous process of the quadrate bears a shallow groove along its ventral surface for attachment with the anteriormost projection of the preopercle (pop), and antero-basally the process merges with a saddle-shaped condyle for the connection with the "coronoid" process of the articular bone (art). The *articular* (figs. 7, 16) is a lanceolate bone which is concave dorso-ventrally along its longitudinal axis. With the angular and dentary it forms the lower jaw. At the posterior end the base of the coronoid process is penetrated by several foramina. On the postero-ventral surface of the articular and sutured antero-basally to the condyle is the reduced *angular* (figs. 7, 16). The articular bone is composed of three anterior processes. The middle projection is the largest and extends anteriorly to fit within the hollow recess of the bifurcate *dentary* (dent), and the small dorsal and ventral protuberances join the upper and lower processes of the dentary (figs. 7, 18), a thin deltoid bone bearing a single row of sharp, inwardly-curving teeth on its upper surface. A deep groove for the articular traverses the length of the dentary, and anteriorly the paired bones become thickened and form a symphysis.

The attachment of the mandibular suspensorium is provided by an inverted L-shaped bone, the *hyomandibular* (hyom, figs. 7, 21). Dorsally, the vertical limb forms a massive structure which serves as a base for three stout condyles. The longest and anteriormost articulates at the junction of the sphenotic (sphot) and pterotic (pto). The configuration of this process is unique in *Thunnus atlanticus*. In four other species it forms a right angle with the axis of the vertical limb but in

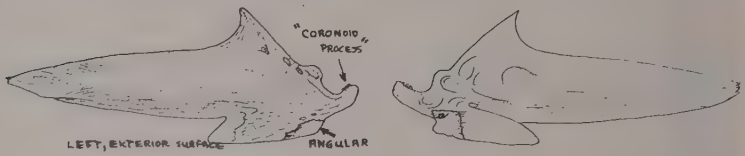


FIG. 16

FIG. 17

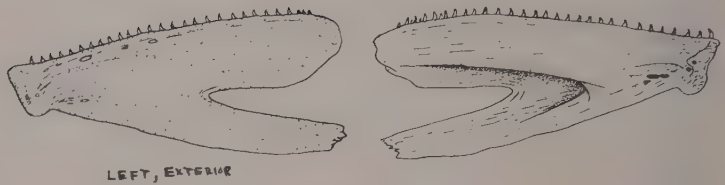


FIG. 18

FIG. 19

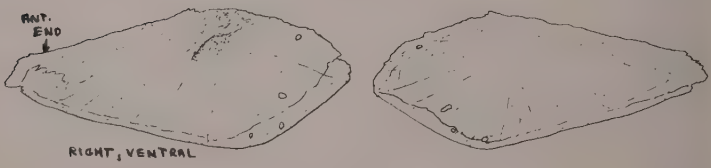


FIG. 20

FIGURE 16, Articular, with angular attached; FIGURE 17, Supramaxillary; FIGURE 18, Dentary; FIGURE 19, Ectopterygoid; FIGURE 20, Entopterygoid.

T. atlanticus it is oblique. While this is not trenchant, the dissimilarity may be seen by comparing fig. 7 and fig. 21 with those of Godsil and Byers (1944: 120, fig. 72). The dorsal condyle articulates with the ventral fossa of the pterotic bone, and the third process laterally articulates with the anterior fossa of the *opercle* (op, figs. 7, 25). Anteriorly, the ventral surface of the hyomandibular joins the metapterygoid, and while the latero-basal portion of the vertical limb is connected to the symplectic, its medio-basal part is joined by cartilage to the *interhyal* bone (ihy, fig. 35). The postero-lateral surface of the hyomandibular bears a deep, obliquely vertical sulcus which receives the anterior surface of the vertical limb of the *preopercle* (pop, figs. 7, 28). While the preopercle is actually part of the mandibular suspensorium, it is usually included in the opercular series, and with the opercle, interopercle and subopercle it constitutes the gill cover. The preopercle is a crescent-shaped bone with its forward edge greatly thickened but attenuated posteriorly. It is composed of a vertical and horizontal limb, both of which bear a shallow groove along their anterior and dorsal surfaces respectively for the articulation of the hyomandibular, symplectic and quadrate bones. The anteriormost projection of the preopercle is connected to the articulating condyle of the quadrate by cartilage. Postero-basally the preopercle overlaps the greater part of the *interopercle* (iop, figs. 7, 26), a thin, curved deltoid bone with its lower surface forming the lower edge of the gill cover. Its inner surface bears a shallow semicircular depression for muscle attachment. The postero-dorsal portion of the preopercle overlays the *opercle* (op, fig. 7, 25), a curved, somewhat orthogonal bone with a much thickened anterior portion bearing an elliptically concave fossa for attachment to the lateral condyle of the hyomandibular. Both the opercle and the interopercle posteriorly cover the greater part of the surface of a thin, polygonal bone, the *sub-opercle* (sop, figs. 7, 27). The posterior margin of the posterior edges of the gill cover are formed by the opercle and preopercle.

The distribution of the cranial scales (fig. 7a) is chiefly postorbital and posttemporal, and those of the suborbital region are not distinct from the *suborbital bones* (so_2, so_3, fig. 7). The oval, overlapping cheek scales extend posteriorly to the preopercular margin. Those forming the posterior margin of the orbit are enlarged, and their anterior portions are curved inward and imbedded in the muscle. The dermal scale bones of the temporal region are thin and polygonal and do not overlap each other. They are connected to one another by

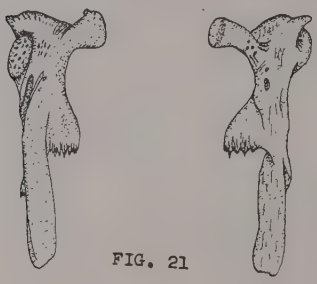


FIG. 21

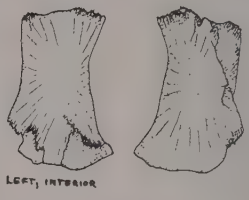


FIG. 22

FIG. 23

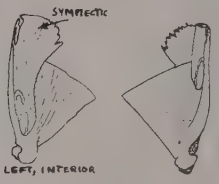


FIG. 24

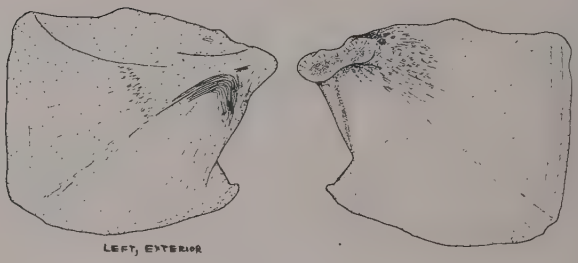


FIG. 25

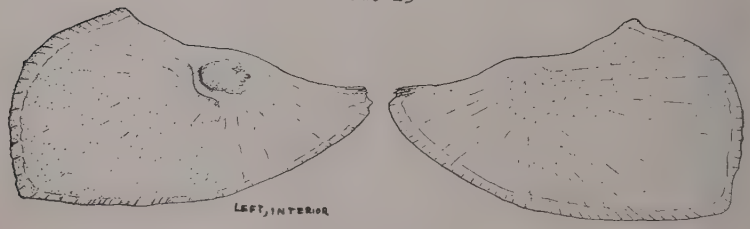


FIG. 26

FIGURE 21, Hyomandibular; FIGURE 22, Metapterygoid; FIGURE 23, Symplectic; FIGURE 24, Quadrate, with symplectic attached; FIGURE 25, Opercle; FIGURE 26, Interopercle.

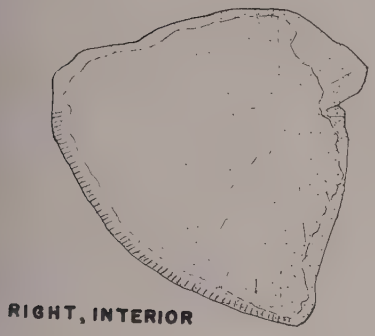


FIG. 27

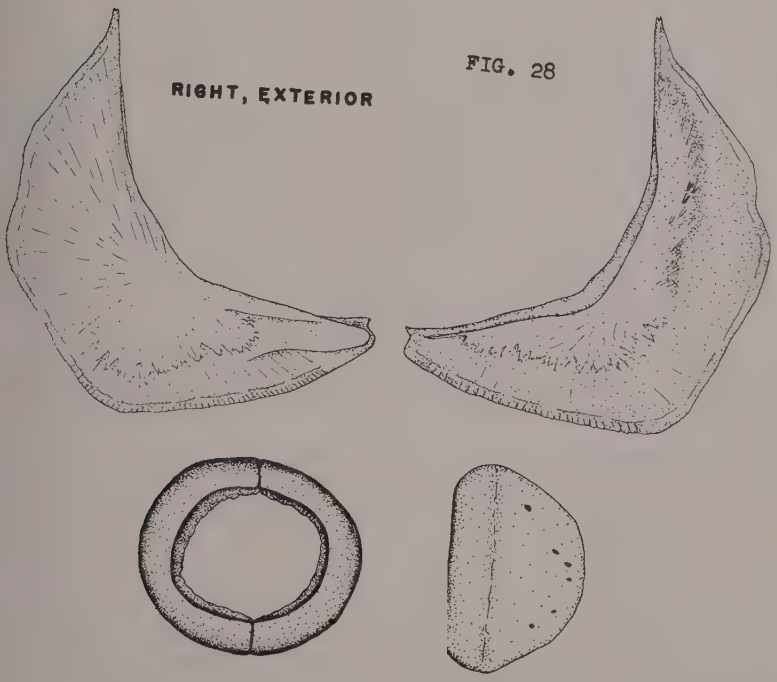


FIG. 28

FIG. 29

FIGURE 27, Subopercle; FIGURE 28, Preopercle; FIGURE 29, Sclerotic bones.

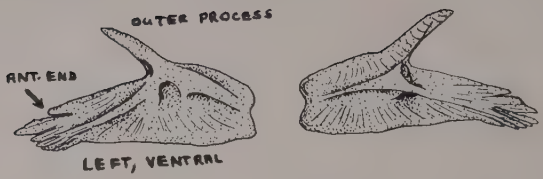


FIG. 30

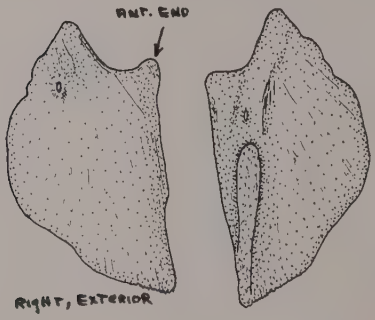


FIG. 31

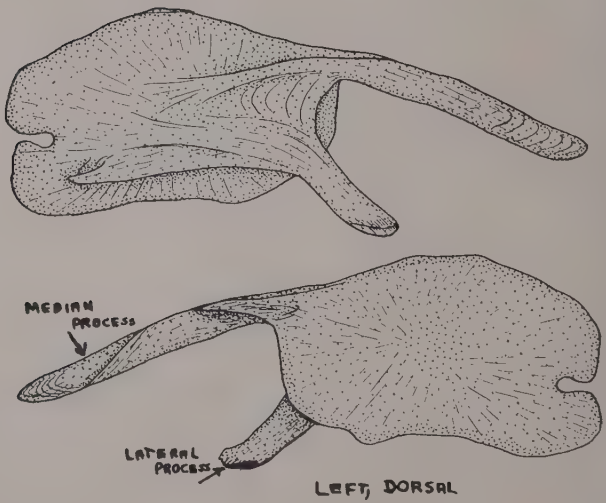


FIG. 32

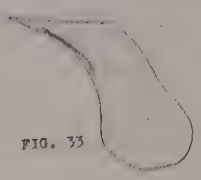
FIGURE 30, Supratemporal; FIGURE 31, Supracleithrum; FIGURE 32, Posttemporal.

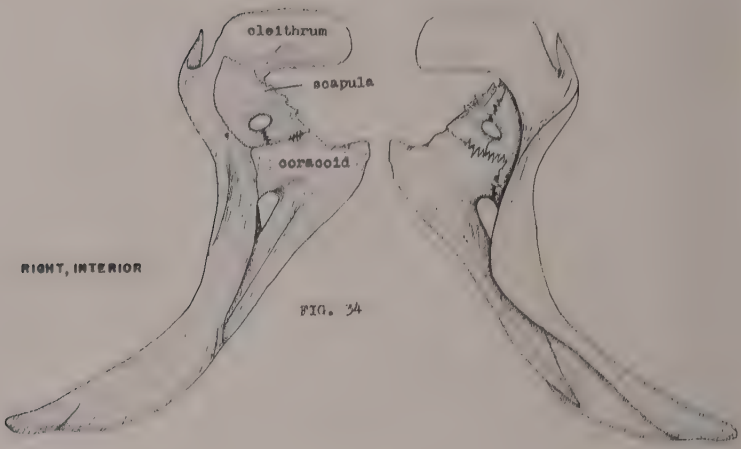
sutures, and a few irregularly spaced scales extend posteriorly between the posttemporal and the supratemporal. Posterior to the latter and the supracleithrum (supcl, figs. 7, 31) there is extensive irregular scalation which gradually merges with the uniformly distributed body scales. The body scales are smooth and secondarily cycloid, and are distributed over most of the posterior portion of the body behind the dermal corselet.

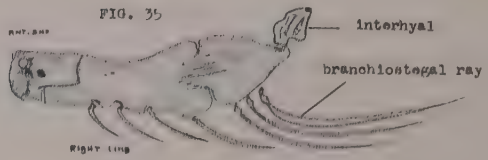
Branchiocranium

While the mandibular suspensorium and the opercular series are considered as part of the branchiocranium, only the hyoid complex and branchial arches are treated under this heading. The *hyoid complex* (figs. 35-38) connects with the base of the hyomandibular and the inner surface of the symplectic by a cartilaginous connection with the interhyal. The posteriormost of these is the *epihyal* (ephy), a flat, triangular bone bearing a small condyle for the *interhyal* (ihy) at its postero-dorsal surface and ventrally articulating with the thickened anterior portions of the first three *branchiostegal rays* (brstg). At its anterior edge slender odontoid processes (fig. 35) firmly interlock the epihyal with similar backward projections from the anterior bone, the *ceratohyal* (cerhy). Its shape is roughly similar to that of the metapterygoid (fig. 22) but it bears a frontal extension for articulation with the *basihyal* (bashy). Several dentate processes on the ventral part of the ceratohyal and their intervening indentations provide the articulating surfaces for the remaining four branchiostegal rays. These rays and their membranous flap attach caudad along the postero-medial surface of the interopercle. Anterior of the ceratohyal, the *basihyal* (bashy, figs. 35, 36) is composed of a fused dorsal and ventral segment which bears a strong lateral projection on its inner surface for the symphyseal connection of the right and left basihyals. The anterior portion of the *urohyal* (urhy, figs. 7, 38) attaches medially at the basihyal symphysis. It is a flattened, sabre-shaped bone which is thickened anteriorly with its attenuated posterior end lying free in the throat muscles. Above the basihyal symphysis, the spatulate, dorsally concave *glossohyal* (gloss, figs. 7, 37) supports the tongue and attaches basally to the basihyals and urohyal. On its ventral side is a deep, elliptical furrow which is penetrated by several foramina.

The *branchial arches* are shown in figure 40 with the epibranchials and "*upper pharyngeals*" lying in the same plane as the ceratobranchials, hypobranchials and basibranchials. However, in life the epibranchials







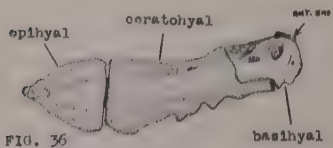


FIGURE 33, Posteleithra 1 (upper) and 2 (lower); FIGURE 34, Pectoral girdle (in part); FIGURE 35, Hyoid complex (in part), internal view; FIGURE 36, Hyoid complex, external view.

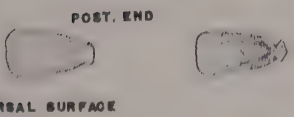


FIG. 37

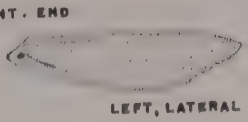


FIG. 38

FIG. 39

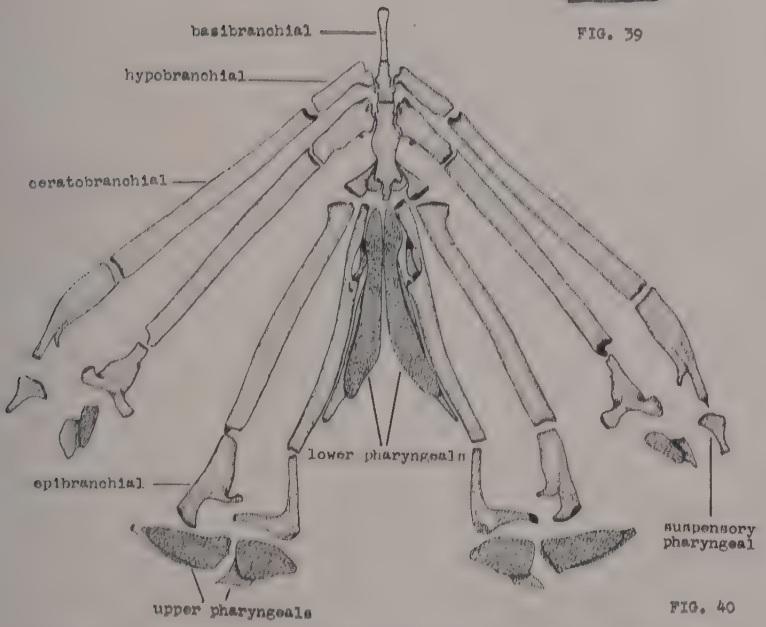


FIG. 40

FIGURE 37, Glossohyal; FIGURE 38, Urohyal; FIGURE 39, Attachment of gillrakers; FIGURE 40, Branchial arches.

and "upper pharyngeal" bones bend sharply forward at an acute angle following their basal juncture with the posterior portion of the ceratobranchials so that the branchial arches appear cuneiform when viewed laterally. The connections between all of the branchial bones are cartilaginous. The *basibranchials* join medially to form the basal support for the lower branchial apparatus. The first basibranchial is joined anteriorly to the posterior portion of the glossohyal at its junction with the basihyals. The second basibranchial resembles an hourglass structure with the lateral indentations forming the articulating surfaces for the first hypobranchial. Posteriorly, the third basibranchial is dorsoventrally flattened and posteriorly attenuated into a cylindrical structure for the articulation of the third and fourth *hypobranchial*. The hypobranchials are rather short structures with their anterior ends modified into irregular articulating surfaces. The *ceratobranchials* and hypobranchials are thin, curved bones, and in cross-section they appear as an inverted "U." The ceratobranchials are very long and they support the greater part of the lower gill arches. The first three are unmodified but the fourth has several irregularities on its inner surface including a medio-ventral process and several foramina. The fifth ceratobranchials are designated here as the "*lower pharyngeals*." Their base is an unmodified ceratobranchial with the dorsal surface covered by a flat plate bearing fine, conical, incurving teeth.

The *epibranchials*, a series of four very irregular twisted bones, are joined basally to the ceratobranchials, dorsally to the pharyngobranchials or "*upper pharyngeals*" and laterally to each other. Of the four pairs of pharyngobranchials, the first, the *suspensory pharyngeals*, are toothless and form the only posterior connection between the neurocranium and the branchial arches. They are connected basally to the first epibranchial and distally to the postero-basal portion of the parasphenoid (pas, figs. 2, 3, 4). The remaining pharyngobranchials are thin irregular bones which have been invested with a heavy dentigerous plate.

While the *gill rakers* (fig. 39) are not part of the skeleton as such, they are considered here because of their osseous nature and because of their taxonomic importance. The gill rakers are short, dentoid structures bearing fine villiform teeth on their anterior surfaces. Basally, two processes surround the convex surface of the ceratobranchials, hypobranchials and epibranchials. The gill raker located at the angle of the gill arch between the ceratobranchial and epibranchial bears a trifurcate basal support for its articulating surface. The gill

rakers are present only on the first gill arch and number from 15 to 19 on the lower limb of the arch and 4 or 5 on the upper, forming a total of 19 to 24 gill rakers. There are from 12 to 14 reduced gill rakers on the inner surface of the first gill bar which are formed from the mediodorsal extensions of the inner supports of the gill rakers. Overlaying the entire surface of the branchial arches a cornified substance gives the appearance of a paved surface. Posteriorly, this paved material becomes imbedded with very fine teeth which gradually increase in size toward their junction with the pharyngobranchials.

Pectoral Girdle

While the pectoral girdle (figs. 7, 30, 31, 32, 33, 34) constitutes a separate entity, some of the anterior bones of the pectoral chain are not distinct from those of the cranial region. The *posttemporal* (ptm, figs. 7, 32) is a flat, elliptical bone bearing two sturdy anterior processes. The innermost articulates with the dorsal surface of the epiotics (epiot) and the lateral process articulates with the dorsal protuberance of the opisthotic (opo, fig. 6). Anterior to and slightly overlapping the posttemporal is the *supratemporal* (stm, figs. 7, 30) or scalebone (Gregory, 1933). It is a flat, thin bone lying just under the surface of the skin where its lateral process articulates with the ventrolateral condyle of the pterotic (figs. 2, 3, 7).

Posterior to the posttemporal is a series of thin, flat bones, designated in figure 7 as scalebones, of which the first two are relatively large, with those behind (not shown in illustration) considerably smaller and gradually tapering in size to their confluence with the body scalation. On the postero-medial surface of the posttemporal a hook like structure receives a dorsal notch of the *supracleithrum* (supcl, figs 7, 31), a somewhat semicircular bone which is thickened greatly along its anterior vertical axis but attenuated posteriorly. It is serrate ventrally and at its antero-medial surface bears an elongate articulating surface for the cleithrum. Posteriorly, the curved *postcleithrum 1* (pcl 1, figs. 7, 33) connects to a second bone, the *postcleithrum 2* (pcl 2). Both of these are thin and convex, and the lower one bears an elongate xiphoid process which extends postero-medially where it is buried in the flesh.

The *cleithrum* (cleith, figs. 7, 34, 54) is a large, sigmoid bone which forms the greater part of the shoulder girdle and delimits the posterior portion of the gill opening. Its dorsal portion is crescent-shaped and curved medially, and antero-dorsally it bears an angular

process below which is a flattened articulating surface for the supracleithrum. The ventral portion of the cleithrum is composed of an inner and an outer section joining at an acute angle and gradually tapering anteriorly to fuse into a lanceolate process which is corrugated on its inner surface at the symphysis of the right and left cleithra.

The posterior portion of the cleithrum is modified at its upper surface to receive the *scapula* (scap, figs. 7, 34), a rhomboidal, ovally fenestrated structure. Externally the fenestra is bisected by the suture separating the cleithrum and the scapula. The latter is posteriorly thickened as an articulating surface for the *pterygials* (ptryg, figs. 7, 54). Ventral to the scapula is a nearly smooth surface for the connection of the *coracoid* (cor, figs. 7, 34) which is composed of a thin, angularly bent xiphoid process ventrally attached to the inner wing of the cleithrum. The dorsal portion of the scapula anteriorly forms a right angle at its medial antero-dorsal junction with the cleithrum and is thickened posteriorly into a flat articulating surface for the *pterygials*. These are cuboidal structures with their posterior edge convex for articulation with the base of the pectoral fin. The first and most ventral of these rests wholly upon the coracoid and is the largest of the four. The second lies partly upon the coracoid and partly upon the scapula, and the third and fourth rest entirely upon the scapula. Dorsal to the fourth pterygial, a scapular protuberance serves as an articulation for the pectoral rays and may actually be a fifth pterygial which has become secondarily fused to the scapula.

Vertebral Column

The *vertebral column of Thunnus atlanticus* (figs. 41, 42, 43, 44, 48, 49) is composed of 39 vertebrae including the fused axis and the hypural plate. With the exception of the last few vertebrae they are rigidly attached to one another so that little lateral movement is possible. The vertebrae are divided into abdominal and caudal vertebrae, with the point of division considered as the occurrence of the sudden elongation of the haemal arches to form a haemal spine, which in the blackfin tuna occurs at the 19th vertebra. The vertebral count is subsequently designated as $18 + 21 = 39$.

The first fused vertebra, the *axis* (figs. 1, 2, 3, 4, 6) is firmly ankylosed anteriorly to the basioccipital concavity and dorso-laterally to the occipital condyles by means of the reduced axial zygapophyses. Between these condyles and posterior to the exoccipital crest is a triangular concavity formed by the exoccipitals for the reception of

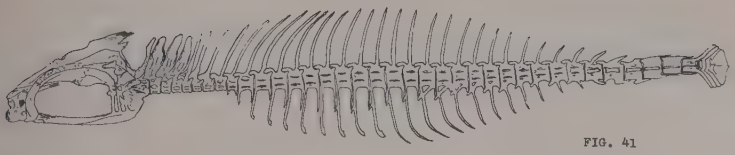


FIG. 41

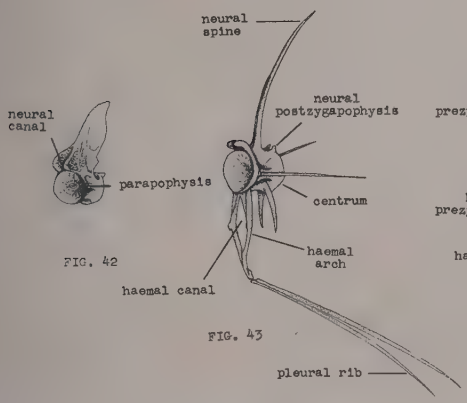


FIG. 42

FIG. 43

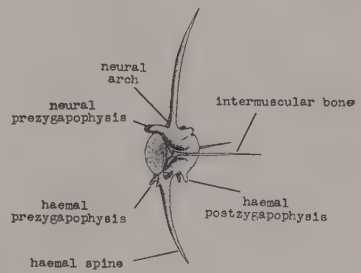


FIG. 44

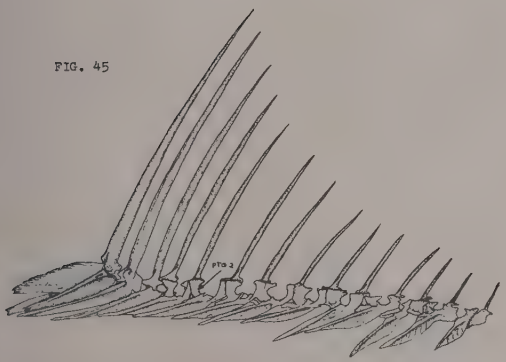


FIG. 45

FIG. 46

FIGURE 41, Neurocranium and spinal column; FIGURE 42, Third abdominal vertebra; FIGURE 43, Seventeenth abdominal vertebra; FIGURE 44, Twenty-third caudal vertebra; FIGURE 45, First dorsal spine and interneurals; FIGURE 46, Single spine with interneural, anterior view.

the *atlas*. The second, third, fourth and fifth vertebrae (figs. 41, 42) bear strong, compressed *neural spines*. The sixth neural spine is only slightly flattened and from the seventh to the twenty-ninth the spines are square and broadly H-shaped in cross-section. This latter configuration is due to the shallow groove traversing the neural spine anteriorly and posteriorly. Basally, the neural spines enclose the narrow neural arch which encircles the nerve cord.

Neural prezygapophyses and *postzygapophyses* are well developed on the centra of all vertebrae, and in the caudal region these are fused with the neural spines to form massive processes which greatly overlap each other posteriorly. The lateral *parapophyses* on the anterior vertebrae become attenuated posteriorly and are consecutively located more ventrally with each vertebra, so that by the tenth vertebra there is a definite *haemal* arch formed from what are termed at this point as *haemapophyses*. On these and the parapophyses are the *pleural ribs* which, beginning with the third vertebra, form the dorso-lateral lining of the abdominal cavity and are broad and compressed anteriorly but become cylindrical posteriorly.

At the eleventh vertebra the two haemal processes unite to form a spineless *haemal arch*. At their junction are two postero-lateral articulating surfaces for the *pleural ribs* (fig. 43) which become lost and are replaced by haemal spines beginning with the nineteenth vertebra. The haemapophyses and haemal spines vary somewhat in their inclination, but in general they are curved slightly forward anterior to the thirteenth or fourteenth vertebra and posteriorly directed behind the fifteenth. On the posterior portion of the centrum the haemapophyses project ventrally and are termed *haemal postzygapophyses*. Beginning with the sixteenth or seventeenth and extending backward to the last vertebra, small angular projections on the front of each haemal arch articulate anteriorly with the haemal postzygapophyses of the anterior vertebra and are designated as *haemal prezygapophyses*. At the twenty-first vertebra the haemal spines secondarily anastomose with the centrum at the base of the haemal postzygapophyses to form a narrow, inclined osseous bridge. The inferior foramen (fig. 41) thus formed is evident to the thirtieth or thirty-first vertebra.

Strong *intermuscular ribs* attach to the apophyses and are present on the sides of the centrum beginning with the first vertebra where they are contiguous with the parapophyses. The anterior ribs are quite long but at about the fifth vertebra they sharply decrease in size and diminish posteriorly to the thirtieth vertebra. Posteriorly, the

neural and haemal spines are gradually reduced in size, and at the thirty-second vertebra there is a marked change in the vertebral structure (figs. 48, 49). The neural and haemal spines become flattened dorso-ventrally to form uniformly flat surfaces, and the parapophyses elongate to form a thin lateral keel projecting horizontally at right angles to the centra to serve as a point for tendon and muscle attachment. The lateral keel on the thirty-sixth vertebra is greatly reduced and disappears on subsequent vertebrae.

While the *hypural complex* is not distinct from the vertebral column, in the family Scombridae it comprises the thirty-sixth through thirty-ninth vertebrae, the first of which has its spines bending abruptly dorsally and ventrally. The thirty-seventh and thirty-eighth are very short but bear stout spines, and the thirty-ninth vertebra or hypural plate is greatly compressed into a roughly triangular structure confluent anteriorly with its narrow, reduced centrum. The neural and haemal spines which have fused together are visible as parallel lines. The advanced phylogenetic position of the genus *Thunnus* is shown by the symmetry of the hypural complex. The only orienting suggestion as to the dorsal or ventral side is provided by an irregular, hook-like urostyle which is attached laterally below the median line of the vertebral axis.

Appendages

Caudal Fin

The *caudal fin* (fig. 53) is sublunate and almost symmetrical in shape with its dorsal lobe slightly longer. There are a total of fifty-one rays, with twenty-five on each side and a single median fan-shaped ray. The fin is flexible posteriorly and the rays are heavily striated, but anteriorly the rays are quite rigid due to the lack of striations in these anterior fin rays. While the anterior rays are subcylindrical in cross-section, the posterior members become greatly compressed and split laterally along their longitudinal axes. Each ray is composed of two mirror-image halves, and, with the exception of the three medio-posterior rays which are attached by cartilage to the end of the hypural plate, these halves straddle the plate at their bases.

Pectoral Fin

The *pectoral fin* (fig. 54) is a long, sabre-shaped structure which reaches to the origin of or past the second dorsal fin but not to the anal fin (table 2). It is composed of thirty-three to thirty-five dicho-

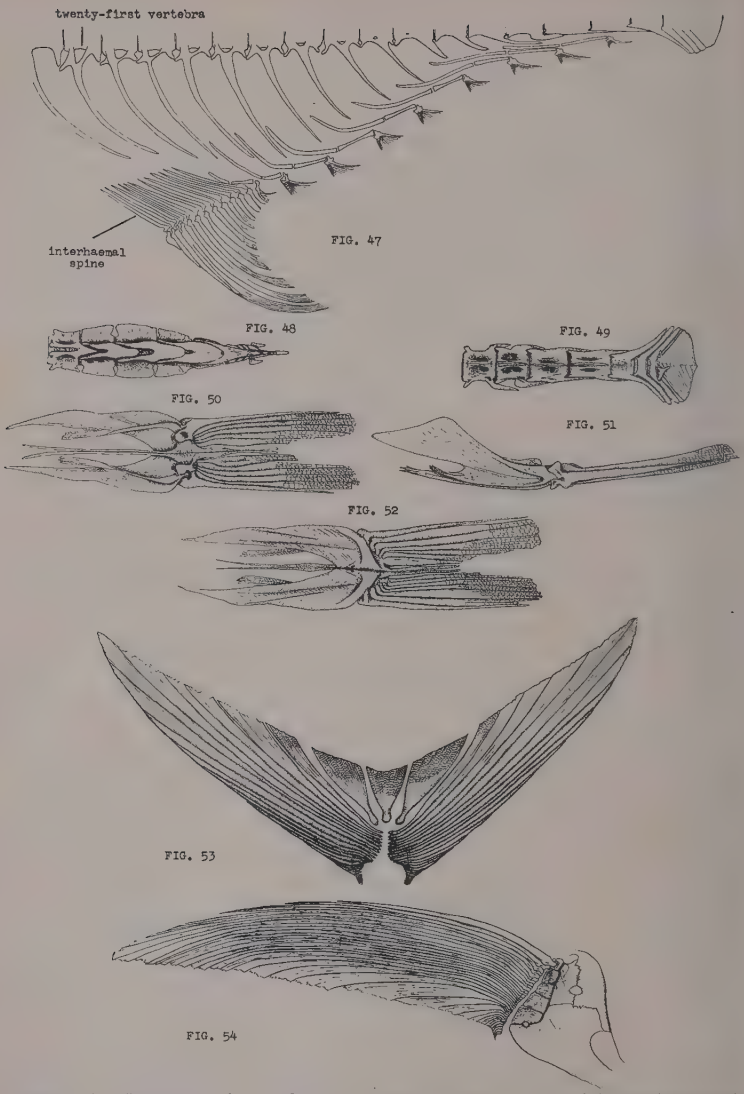


FIGURE 47, Structure of anal fin and finlets; FIGURE 48, Caudal vertebrae and hypural complex, dorsal view; FIGURE 49, Caudal vertebrae and hypural complex, lateral view; FIGURE 50, Pelvic girdle and fins, ventral view; FIGURE 51, Pelvic girdle and fins, lateral view; FIGURE 52, Pelvic girdle and fins, dorsal view; FIGURE 53, Caudal fin; FIGURE 54, Pectoral fin.

tomous rays which straddle the pterygials and parts of the corecoid and scapula at their bases. The superior rays are strong and rigid, but the lower rays are flexible and weak at their distal ends. There are no transverse striations in the rays.

First Dorsal Fin

The *first dorsal fin* (fig. 45) is composed of thirteen or fourteen semi-rigid spines which exhibit an evenly-sloping backward contour diagnostic of the genus *Thunnus*. The vertical groove on the anterior and posterior surface of each spine, with the exception of the first which bears no anterior groove, is a vestige of the primitive dichotomous fin ray in which each ray is composed of a right and left segment. The dorsal spines are basally bifurcate into a right and left condyle for articulation with the interneural spine. The last four fin spines bear a pair of posterior processes near their bases which posteriorly articulate with the fin rays when in a depressed position.

Between the basal bifurcations of the fin spines (fig. 46) the *third pterygiophore* (ptg 3) appears to have lost its function in the Scombridae. In more primitive groups of fishes such as the Salmonidae, the three pterygiophores articulate consecutively so that the third pterygiophore has a supportive function. However, in the Scombridae, the *second pterygiophore* (ptg 2) is expanded dorso-laterally to receive the articulating condyles of the neural spine and with the first supports the dorsal fin. The *first pterygiophore* (ptg 1) or *interneural spine* is a sabre-shaped structure and is broadly expanded at its base and gradually tapered posteriorly in the first six spines. At its dorsal portion, the bifurcate processes articulate with those of the neutral spine. The V-shaped second pterygiophore is similar to the dorsal bifurcate portion of the haemal spine, and its shallow groove serves as a receiving trough for the depressed dorsal fin.

Second Dorsal and Anal Fin

The *second dorsal fin* and *finlets* are mirror images of the *anal fin* and *finlets* (fig. 47), except for their relative position and the number of parts involved, and, therefore, no illustration of the second dorsal fin and finlets is included. The second dorsal fin is composed of 12 to 15 soft rays and 8 or 9 finlets. The anal fin is composed of 12 to 14 soft rays and the posteriormost of these rays is distinct from the first finlet only by dissection of its basal elements.

The anal rays are finely split longitudinally but are unsegmented.

The interpretation of the second dorsal and anal elements as rays or spines has been generally neglected in the Scombridae. While most authors have listed the second dorsal and anal fins as being composed entirely of rays, Clothier (1950: 53) has recognized the anterior elements of the second dorsal and anal fins as true spines and has listed them as such in his diagnoses. He found one spine and from twelve to fourteen dorsal rays, and two spines and ten to eleven anal rays in *Sarda,* and two spines and twelve anal rays in *Katsuwonus.* While the criterion he used to detect spines was not stated, it is assumed that the absence of branching and segmentation were used to indicate a spine. If this is to be accepted, then the author recognizes three anal spines (fig. 47) and three dorsal spines in *Thunnus* (*atlanticus*). However, while the establishment of the presence of spines or rays is an important academic problem, as a practical solution to the problem and in view of past studies from the point of view of statistical consistency, *all* elements should be designated as rays. This method is adopted in the present study, and the difficulty of distinguishing dorsal and anal elements is further discussed.

While the fin ray bases are almost spherical and bear a slight anterior protuberance, with the exception of the first, the anal bases are subcylindrical and bear both anterior and posterior protuberances. The structure of the finlet is that of a "V", with very slender rays interposed between the much thicker first and last rays. The first ray of each finlet is conspicuously segmented but the remainder are faintly or not at all marked. While the interneural spines of the second dorsal and the anal interhaemal spines are single, flattened structures, those of the finlets are cylindrical to subcylindrical in cross-section and are split into two contiguous parts. The occurrence of the first coupled interneural or interhaemal is the criterion used to designate the origin of the first finlet.

The number of finlets and fin rays fluctuates within 2 or 3, and in figure 47 it is obvious that externally what appears to be the last anal ray is actually the first finlet according to this criterion. Consequently, in performing a count without the aid of dissection it would be a simple matter to mistake a ray for a finlet or vice-versa. Therefore, in order to eliminate unnecessary dissection, the author suggests that in future systematic studies on the Scombridae all counts should be considered as *total* dorsal or anal *elements* rather than as separate fin and finlet counts. For example, in figure 47 the anal ray count might be construed either as A-12, finlets IX or as A-13, finlets

VIII. Since the exact status is determinable only by dissection, the practicable solution would be to list the count as A-21. It is hoped that this suggestion will facilitate future field and systematic studies on the Scombridae.

Pelvic Girdle

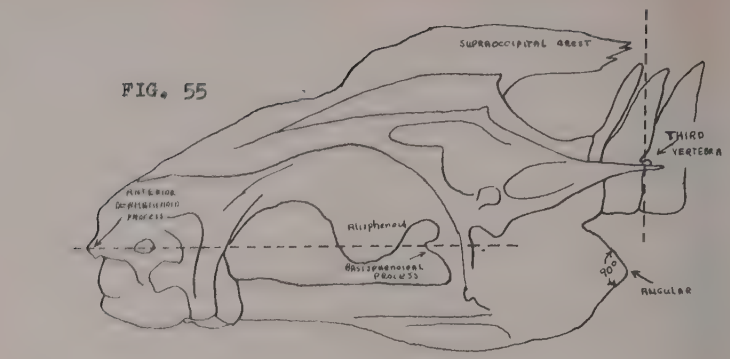
The *pelvic girdle* (figs. 50-52) is located ventrally to the insertion of the pectoral fin and is buried in the flesh. The girdle is composed of two anterior *basipterygia* or "ischio-pubic" bones which are firmly joined by a suture, and the posteriormost dermal *fin rays*. There are no radialia as in primitive fish groups, and the dermal fin rays articulate directly with the basipterygia. The pelvic fins are composed of one spine and five soft rays, the latter heavily striated at their tips. The rays are semi-rigid at their basal portions and their articulating surface is broadly angular. Each basipterygium bears a blade-like dorso-lateral process bearing two antero-ventral extensions. The first of these is essentially part of the dorso-lateral extension, while the second is an anterior xiphoid process of the ventral part of the basipterygium which continues posteriorly as a shorter and stouter posterior xiphoid process.

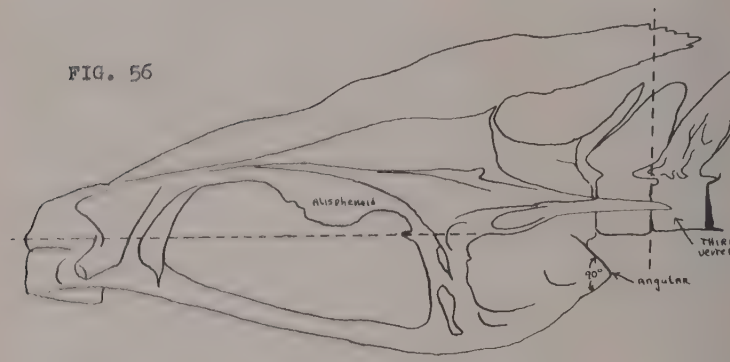
Comparisons, Relationships and Phylogenetic Position

A comparison of the skeleton of *Thunnus atlanticus* with four other species of *Thunnus* used in this study is shown in Tables 1 and 2. The bones listed in Table 1 are only those which showed consistent differences.

Arbitrary values have been assigned to similarities and differences so that the relationships among the species can be listed quantitatively in order to give an index of the phylogenetic position of *atlanticus* in the genus *Thunnus*. Bones which show difference are rated as zero units, and those which are similar are rated as one unit. In addition, Table 2 shows the osteological characters of species of *Thunnus* and its closest relatives, *Euthynnus, Katsuwonus* and *Sarda*.

To supplement the available material and in the absence of a larger number of specimens for this study, the works of Godsil and Byers (1944: 22), and Clothier (1950: 27) were freely drawn upon, since their studies involved analyses of large numbers of specimens. In the preparation of the osteological key to the species of *Thunnus*, the characters used by these authors were found to be very satis-





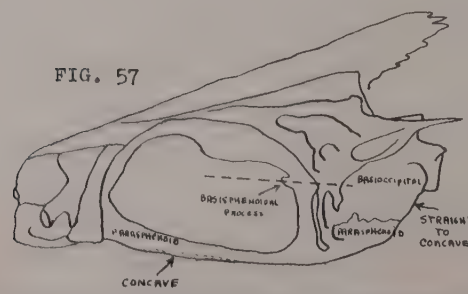


FIGURE 55, *Thunnus thynnus*, lateral view of neurocranium; FIGURE 56, *Thunnus alalunga;* FIGURE 57, *Thunnus atlanticus*.

factory. While the number of trenchant differences found were few, several important cranial and vertebral characteristics were noted which would separate the species in a key. The basisphenoid, parasphenoid, basioccipital and location of the first closed haemal arch afforded the best indication of relationships and were used to show phylogeny in the species of *Thunnus*.

The following osteological diagnosis and key serve to characterize the genus *Thunnus* and to identify and indicate the phylogenetic relationships among the species herein considered:

Alisphenoids meeting in the median line; vomerine teeth present; first vertebra reduced in size, ankylosed to the skull; vertebrae typically 18 + 21 = 39, without haemal osseous bridge or interhaemals; first closed haemal arch occurring at 10th or 11th vertebra; first haemal spine occurring at 19th vertebra; total number of gill rakers 19-41 on first gill arch; pectoral rays 33-37; dorsal spines 13 or 14; dorsal fins close together, the outline of the first gradually tapering posteriorly.

Osteological Key to the Species of *Thunnus*

1a.—First closed haemal arch occurring typically at the tenth vertebra. Posterior cranial margin formed by basioccipital and parasphenoid bent sharply to form an acute angle of 90 degrees or less.

2a.—Supraoccipital crest not extending backward beyond joint between second and third vertebra. Alisphenoids extending down more than halfway into interorbital opening below a line drawn from the anteriormost point of the dermethmoid to the median antero-dorsal process of the basisphenoid. First haemal arch triangular, not bent forward at an angle of 45 degrees to the vertebral column.

Thunnus thynnus

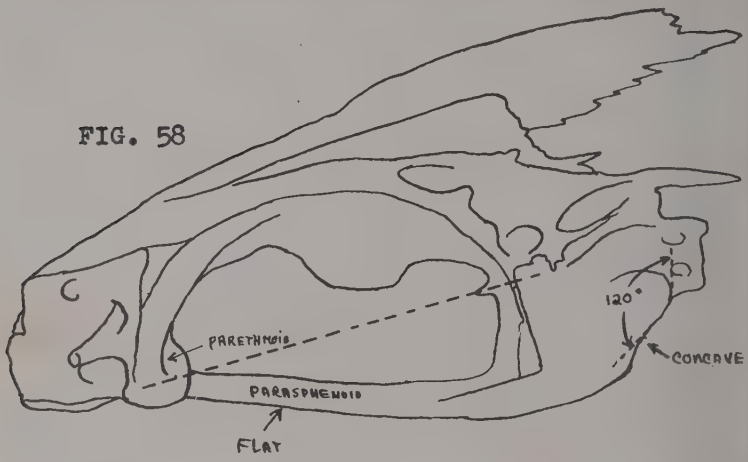
2b.—Supraoccipital crest extending between second and third and nearly to centrum of fourth vertebra. Alisphenoids not extending down more than halfway into interorbital opening below a line drawn from the anteriormost point of the dermethmoid to the median antero-dorsal process of the basisphenoid. First haemal arch subcircular, bent forward at an approximate angle of 45 degrees to the vertebral column.

Thunnus alalunga

1b.—First closed haemal arch occurring typically at the eleventh vertebra. Posterior margin of basioccipital rounded or forming an obtuse angle of 120 degrees or more.

3a.—Ventral surface of parasphenoid decidedly concave in cross-section behind vomer. Median antero-dorsal process of basisphenoid extending forward in a line drawn parallel to the parasphenoid.

Thunnus atlanticus



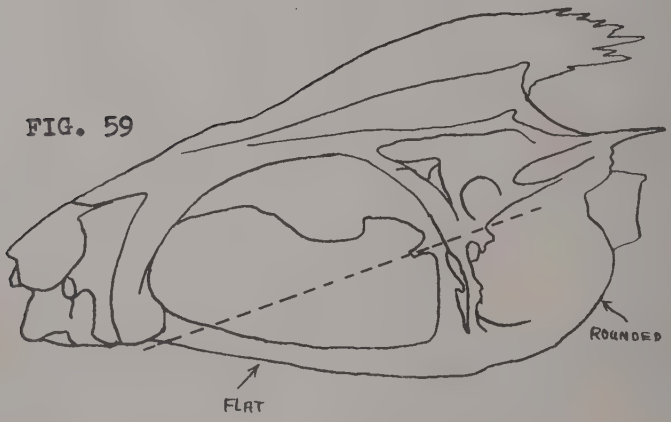


FIGURE 58, *Thunnus albacares;* FIGURE 59, *Thunnus sibi.*

3b.—Ventral surface of parasphenoid flat in cross-section behind vomer. Median antero-dorsal process of basisphenoid extends forward and

down in a line which transects at or behind the postero-dorsal junction of the parasphenoid and the parethmoids.

4a.—Posterior margin of cranium formed by the parasphenoid and basioccipital straight, concave or includes a slightly obtuse angle when viewed laterally.

Thunnus albacares

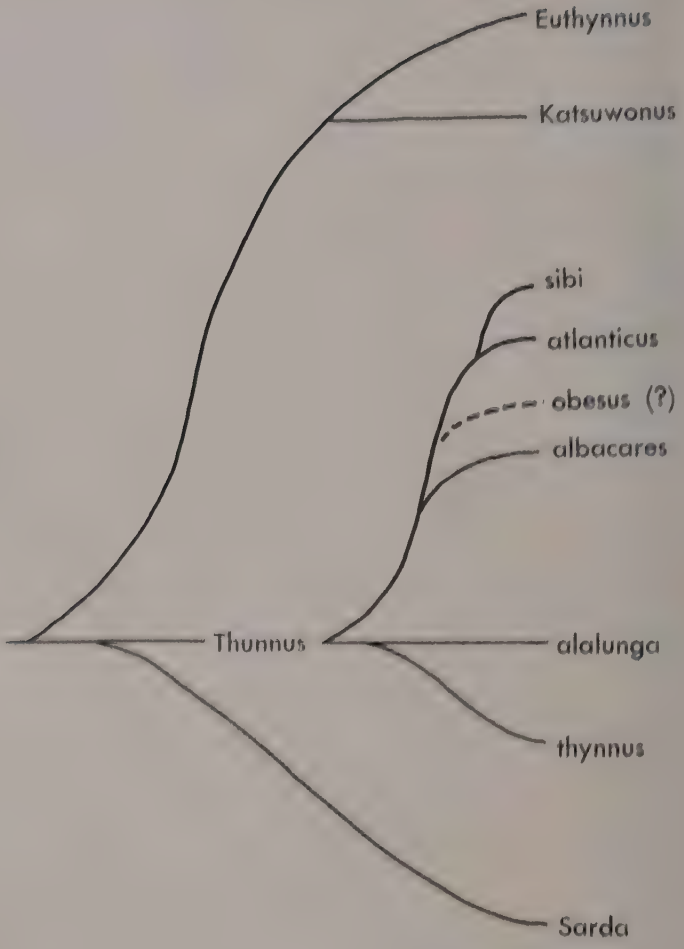
4b.—Posterior margin of cranium formed by the basisphenoid and basioccipital rounded convexly.

Thunnus sibi

From the observations on the similarities and differences among the genera of *Thunnus, T. atlanticus* appears to be intermediate between *T. sibi* and *T. albacares,* with closer affinities with the latter. Osteologically, these three species resemble each other more closely than they do the other species of the genus, and form a compact group (subgenus?) on the basis of the location of the first closed haemal arch and the conformation of the posterior margin of the cranium. Conversely, a similar group is formed by *T. thynnus* and *T. alalunga* which resemble each other very closely in their osteology.

It is the purpose of this study to show relationships rather than artificially to subdivide the species of *Thunnus* into lesser categories. In the author's opinion, the names *Parathunnus* and *Neothunnus* proposed by Kishinouye (1923) seem to be artificial on the basis of osteological evidence and on other characters pointed out by L. R. Rivas (personal communication). If *Parathunnus* were to be considered as a valid genus, then on the basis of osteological evidence, *Neothunnus* should be united with it since it is closer to *Thunnus atlanticus* than to *Thunnus sibi.* On the other hand, *Thunnus thynnus* and *Thunnus alalunga* are very close to each other osteologically, and the inclusion of the latter into a separate genus (*Germo*) is not warranted on the basis of osteology.

In view of the compact group represented by the genus *Thunnus* in relation to its closest relatives (Table 2), *Euthynnus, Katsuwonus* and *Sarda,* the designation of the genus *Thunnus* as a separate family by certain authors seems to be osteologically untenable. The members of the family Scombridae are more closely related to each other than to any other group. *Euthynnus* and *Katsuwonus* form a natural group on one side of and close to *Thunnus* while *Sarda* forms a natural group on the other side. Examination of the skeletons of the aforementioned genera (Godsil and Byers, 1944; Kishinouye, 1923; Starks, 1910; Clothier, 1950) shows that while *Auxis, Euthynnus* and *Katsuwonus*



PHYLOGENETIC POSITION OF THUNNUS ATLANTICUS

FIGURE 60, Phylogenetic position of *Thunnus atlanticus*.

stand as a compact group, above generic rank, they are closely related osteologically to *Thunnus* and to a lesser extent to *Sarda*.

The proposal of the families Thunnidae, Scombridae, Katsuwonidae and Cybiidae by Kishinouye (1923) automatically implies that the presently accepted family Scombridae should be considered as a higher grouping of ordinal or subordinal rank. Starks (1910: 79-83) has presented a key and phylogenetic relations of the family, and his evidence shows conclusively that at best some of the families proposed by Kishinouye should be considered as subfamilies.

Additional meristic osteological characters in Table 2 permit a classification of the various species into categories similar to, but less natural than those arrived at from osteological evidence presented in this study. The use of any one of these as a diagnostic character to further split the genus results in various overlapping schemes of classification. Such artificial subdivision of the genus *Thunnus* has occurred in the past as a result of too much emphasis having been placed on either internal or external characters and almost complete disregard for the correlation between both.

While certain external characters may be used to form one grouping, the use of internal characters results in an entirely different scheme of classification, so that the total combination of characters

TABLE 1

Osteological Comparisons of *Thunnus atlanticus* With Four Other Species of *Thunnus* Showing Degree of Relationships. Zero Units Indicate Difference; One Unit Indicates Similarity.

T. atlanticus	*albacares*	*sibi*	*alalunga*	*thynnus*
neurocranium	1	1	0	0
first closed haemal arch	1	1	0	0
interopercle	1	0	0	0
quadrate	0	1	0	0
cleithrum	1	0	0	0
opercle	1	0	0	0
subopercle	0	1	1	0
preopercle	1	0	0	0
supratemporal	0	1	0	0
supracleithrum	0	0	1	0
sclerotic bones	0	1	0	0
pelvic girdle	1	0	0	0
epi,-ceratohyal	0	0	0	1
articular	0	0	0	1
parasphenoid	1	0	0	0
pectoral fin	1	0	0	0
vomer	1	0	0	0
total	10	6	2	2

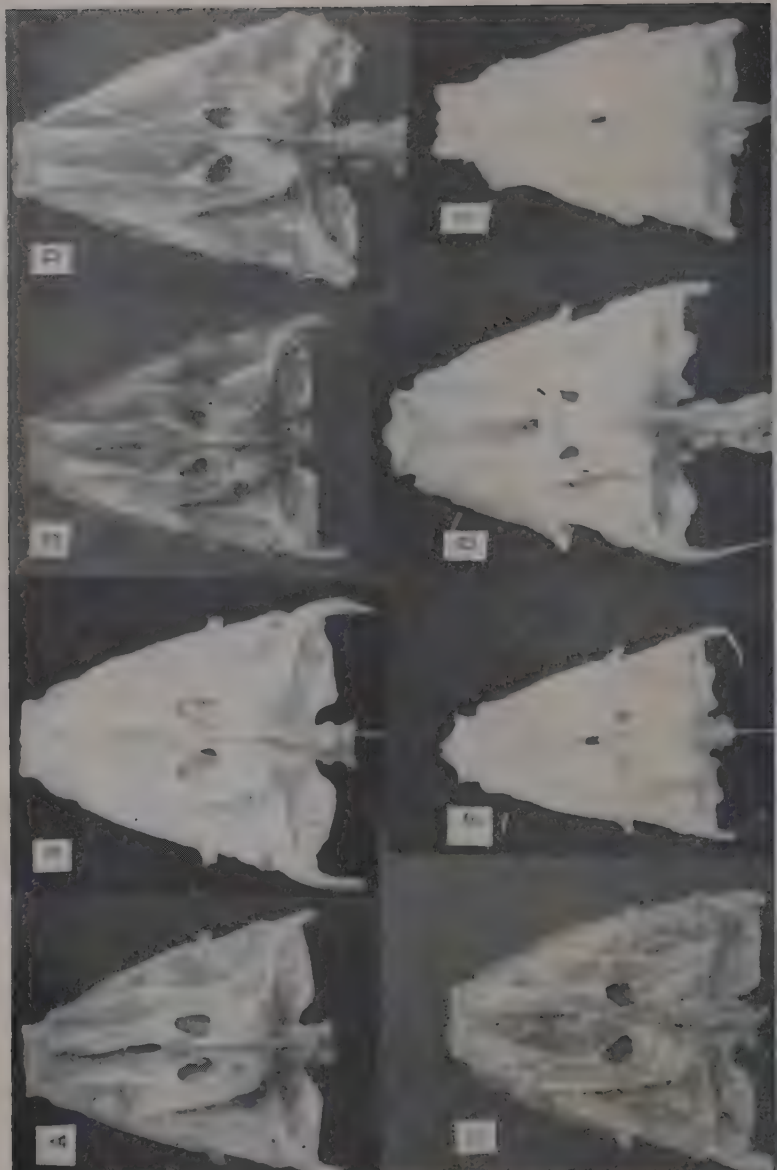


FIGURE 61. Dorsal view of neurocrania of the tuna and tuna-like fishes. A, *Thunnus atlanticus*, Miami, Florida; B, *Thunnus albacares*, Pinas Bay, Panama; C, *Thunnus sibi*, southern California; D, *Thunnus alalunga*, southern California; E, *Thunnus thynnus*, California; F, *Katsuwonus pelamis*, Miami, Florida; G, *Euthynnus alletteratus*, Miami, Florida; H, *Sarda orientalis*, Pinas Bay, Panama.

TABLE 2

OSTEOLOGICAL CHARACTERS OF THE GENUS *Thunnus* AND RELATED GENERA

Character	*T. atlanticus*	*T. sibi*	*T. albacares*	*T. obesus*	*T. alalunga*	*T. thynnus*	*Euthynnus*	*Katsuwonus*	*Sarda*
Total number of vertebrae	39	39	39	39	39	39	39	41	44-46
First closed haemal arch occurring at vertebra number:	11	11	11	*	10	10	*	12-13	12-14
First haemal spine occurring at vertebra number:	19	19	19	*	19	19	21	21-22	22-24
Gill rakers, upper limb	4-5	7-8	7-10	9	8-10	12-14	8-10	16-22	2
Gill rakers, lower limb	15-19	17-20	19-22	20-22	19-21	25-27	26-29	35-43	7-14
Gill rakers, total number	19-24	24-28	26-32	29-31	27-31	37-41	34-49	51-65	9-16
Pectoral fin reaching to:	origin or past D_2 but not to anal	past D_2	origin or past D_2 but not to anal	origin or past D_2 but not to anal	past origin of anal	spine 10-12th	10-12th spine	8-9th spine	8-12 spine
Pectoral rays	33-35	33-35	33-35	34	33-35	33-37	28	26-27	24
Dorsal spines	13-14	13-14	13-14	13-14	13-14	13-14	15-16	15-16	15-22
Dorsal rays	12-15	15	14-16	13-15	15-16	13-15	12-13	14-16	13-15
Dorsal finlets	8-9	8	8-9	8	7-8	8-10	8-9	7-8	6-9
Dorsal rays plus dorsal finlets	20-23	22-23	23-24	21-23	22-23	22-24	20-21	21-24	22
Anal rays	12-14	14	13-14	13-14	14-15	13-15	11-14	14-16	12-16
Anal finlets	7-8	8	7-9	7-8	7-8	7-9	6-7	6-8	6-7
Anal rays plus anal finlets	21-22	21-22	21-22	20-22	21-22	21-23	18-21	21-23	22

*Data insufficient

results in the nullification of further subdivisions on any other but the species level. In attempting to include *atlanticus* under the genus *Parathunnus*, it is found that this species is more similar to *albacares* than to *sibi*, and therefore the names *Parathunnus* and *Neothunnus* could not be accepted even as subgenera.

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RELIABILITY OF COMMERCIAL VESSEL REPORTS OF SEA SURFACE TEMPERATURES IN THE GULF OF MEXICO

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Contribution from the Department of Oceanography of the Agricultural and Mechanical College of Texas, Oceanography and Meteorology Series No. 38; based in part on investigations conducted for the Texas A. and M. Research Foundation through the sponsorship of the Air Force Cambridge Research Center, Air Research and Development Command.

Abstract

The temperature distribution of the surface water in the Gulf of Mexico as determined by certain short period averages of commercial vessel reports is shown to be reliable. Comparison is made with the distributions as determined for three periods from data obtained by scientific oceanographic surveys made in 1951 and 1952. Comparison is also made with mean monthly sea surface temperatures. The limitations of the latter are mentioned, and the suggestion is made that running short period averages of commercial vessel reports be used for practical purposes, *i.e.*, meteorological and oceanographic research, and forecasting air mass modification over the Gulf.

Introduction

The particular results of scientific analyses depend, to a large degree, on the quality and quantity of the data being analysed. In meteorological and oceanographic investigations of processes involving surface water temperature, the accuracy and number of measurements of this parameter are critical. Since scheduled ocean observations are few for the area involved, it becomes desirable to augment them with commercial vessel reports. However, the reliability of the latter, at least of any individual report, is rather doubtful. It therefore is necessary to study the extent to which commercial vessel reports of sea surface temperature may be used.

Since 1951 more complete oceanographic cruises have been undertaken in the Gulf of Mexico than previously. These scientific one-vessel expeditions, constituting the first extensive survey made of the Gulf, take measurements of surface water temperatures. As a first approximation, the values recorded on each cruise form the basis for determining the temperature pattern over the area and for the period involved. Consequently, it is possible to estimate the reliability of the temperature distribution as determined from averages of commercial vessel reports for the same period, by comparison with the scientific cruise pattern. Here, of course, the cruise data are assumed correct, and further, the temperature is considered relatively constant during

the cruise period.

In itself, comparison of the two patterns is straightforward. However, sea surface temperatures as measured on the scientific cruises by bucket thermometers actually pertain to the top 1-2 feet of water. On the other hand, temperatures taken by commercial vessels are a result of measurements usually made in the ships' condenser intake. These readings consequently pertain to a depth of from 10-20 feet depending on the size of the ship. Therefore, inherent in the comparison of the two patterns is this factor of the existing temperature gradient between the different levels. Brooks (1926) has shown, by a detailed and carefully controlled investigation, that under virtually all conditions, condenser intake temperatures are representative of the sea surface. The difference between the two is largest on calm clear afternoons but on the average is less than 1°F. Essentially then, the proposed comparison would seem to give an estimate of the reliability of commercial vessel measurements made in this quasi-isothermal layer.

Existing information on the sea surface temperature distribution in the Gulf of Mexico is largely climatological, *i.e.*, long period monthly averages of commercial vessel observations. The most recently prepared charts by Fuglister (1947) involve observations of approximately 30 years. Other similar works include; Slocum (1934, 1935, 1936), considering observations of about 20 years, and U.S. Weather Bureau (1938), involving a period of 50 years. In general, there is a good agreement among these various charts. However their use is restricted by the usual limitations involved in long period averages. Many of the details and short period features which were brought out by recent oceanographic cruises are completely masked by the averaging process.

In this study, short period averages (12-19 days) of commercial vessel reports of sea surface temperatures are used to determine the distribution of this parameter in the Gulf of Mexico. This pattern is then compared with that based on oceanographic cruise measurements made over large areas in the Gulf during the same period. Three such comparisons are made.

Source of Data

The Department of Oceanography of the A. & M. College of Texas furnished the oceanographic cruise data.[1] Periods involved in this

[1] The temperature measurements were made on the U S. Fish and Wildlife Service vessel, M/V ALASKA, by the Texas A. & M. Research Foundation under the sponsorship of the U. S. Navy, Contract No. N7onr-48702.

study are: 10-21 August 1951, 9-27 January 1952, and 20 May-6 June 1952. Measurements were made to the nearest tenth of a degree Fahrenheit using a standard, shielded, fish-type bucket thermometer. Temperatures measured by use of this instrument are considered representative of the top 2 feet of water.

Reports of commercial vessels for the same periods were furnished by the Climatological Services Division of the U. S. Weather Bureau. The number of reports ranged from 900 for the August period to 1500 for the May-June period. The bulk of these observations were for the main shipping lanes. Very few were available in the northeast and southwest sectors of the Gulf. All values were used regardless of the time of day the observations were made. These measurements are to the nearest whole degree Fahrenheit, and are mainly condenser-intake temperatures.

Charts of the mean monthly distribution of sea surface temperatures were prepared by Fuglister (1947).

Computation of Commercial Vessel Averages

The Gulf of Mexico was divided into one degree latitude-longitude quadrangles. For each cruise period simple arithmetic averages of all reports in each quadrangle were computed to the nearest tenth of a degree Fahrenheit. The number of observations in these unit areas ranged from zero to upwards of 80. In areas where the number of observations were few, *e.g.*, off the major shipping lanes, corrections were applied to the reported values. These corrections were derived in the following arbitrary manner. A determination was made of the deviation of each report of a given vessel from the computed average temperature (nearest whole degree) of the quadrangle in which the vessel was located. This deviation was considered only when there were at least 3 other reporting vessels in the unit area. If these differences were of one sign for more than 80 per cent of the vessel's observations, their average was considered a good approximation to the correction necessary. The majority of corrections made were to reports of vessels that were consistent in sign of error, *i.e.*, either too high or too low all of the time. Corrections were applied only in quadrangles with fewer than 10 reports.

The majority of corrections were 2° F or less. Some vessels which were consistently in error required corrections of 3° to 5° F. There were few 10° F deviations. In this latter instance the report was not used in computing the average for a quadrangle. One feature of the

reports was that they showed a preference for even-number degrees. This is likely due to the graduations on the thermometers used. Another point noted in computing the 1° quadrangle averages was that the medians and means were in most cases the same. When a mode existed, its value was also the same as the mean. Generally the differences between these three values were less than 1° F.

Presentation

The average sea surface temperature for each 1° quadrangle determined from commercial vessel reports for the three periods involved is shown in Figures 1a, 2a, and 3a. The temperature in degrees Fahrenheit is entered in bold print above the center of the quadrangle. Values in italics, entered below the center of each quadrangle, represent the number of observations involved in each computation. No entry in an area indicates no data were available. Isotherms, labelled in °F, are included as a possible analysis. In areas where data were scarce the isotherms are dashed or omitted entirely. Values of isotherms are encircled.

The distribution of surface water temperature as derived from the cruise data is reproduced in Figures 1b, 2b, and 3b. For purposes of comparison, average sea surface temperature charts (Fuglister, 1947) for January and May are reproduced in Figures 4 and 5.

Figure 6 is a scatter diagram of commercial vessel average temperatures (T, °F) versus oceanographic cruise data (to, °F) for areas where both coexist. The cruise values represent the temperatures, to the nearest whole degree Fahrenheit, at the center of the 1° quadrangles. The plot covers three cruise periods.

Comments on Comparisons

The similarities of the patterns of commercial vessel and cruise data are apparent in Figures 1, 2, and 3. Warm and cold tongues and pockets on both sets of charts compare very well in location as well as magnitude of temperature. In some instances the features of the commercial vessel patterns are displaced slightly or are not as pronounced as those of the cruise data. These relatively minor differences may be due to variations in temperature during the cruise period. Since the average temperature over an interval of time is being compared with an instantaneous reading made during the interval, some slight differences should be expected. Other minor differences exist in areas where there are few ship reports.

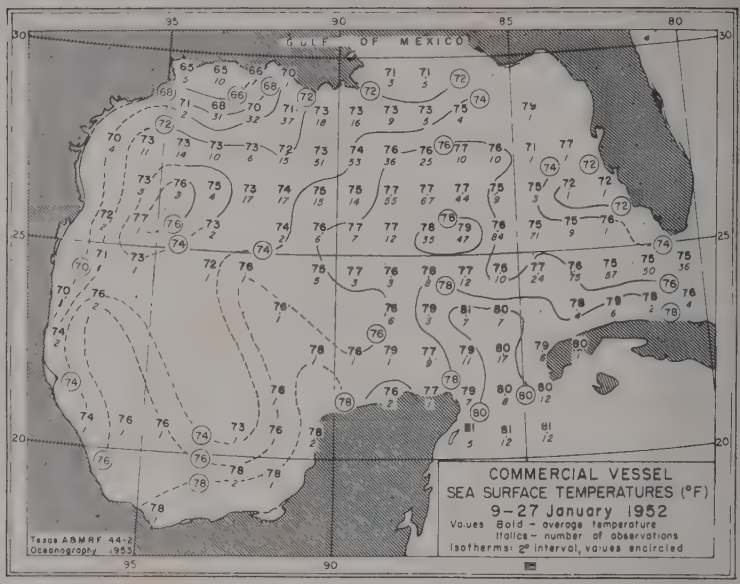

FIGURE 1a

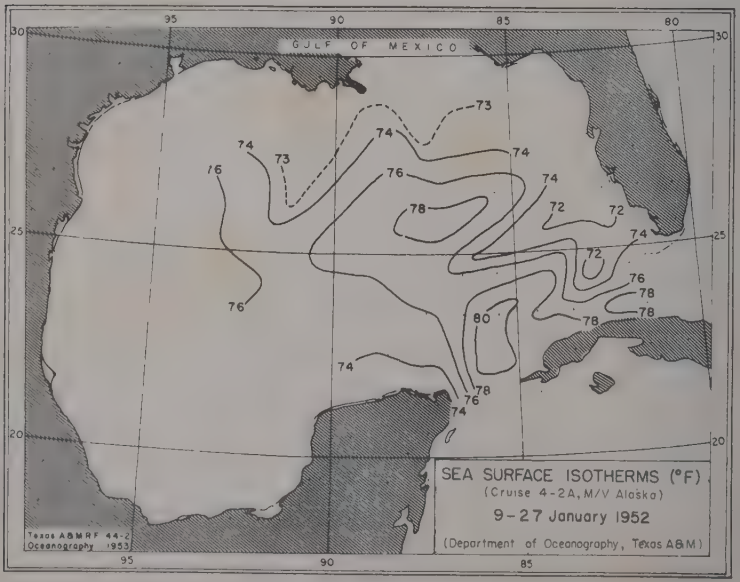

FIGURE 1b

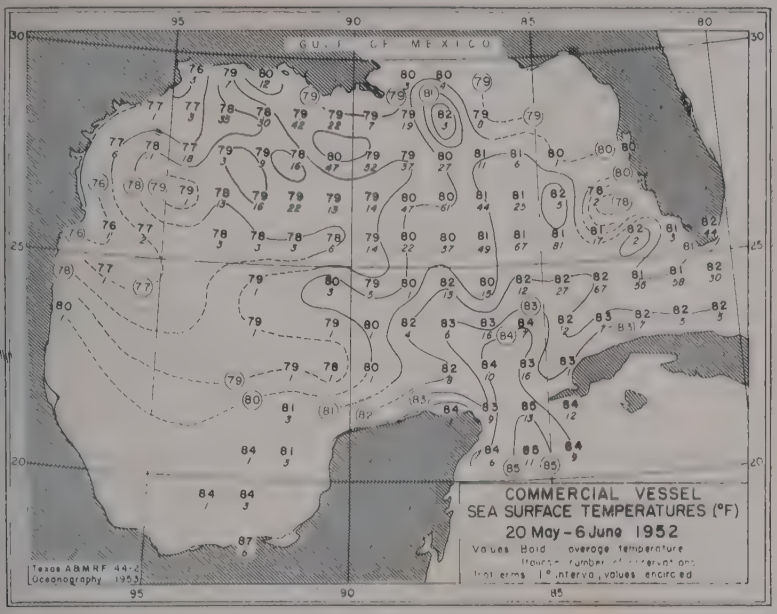

FIGURE 2a

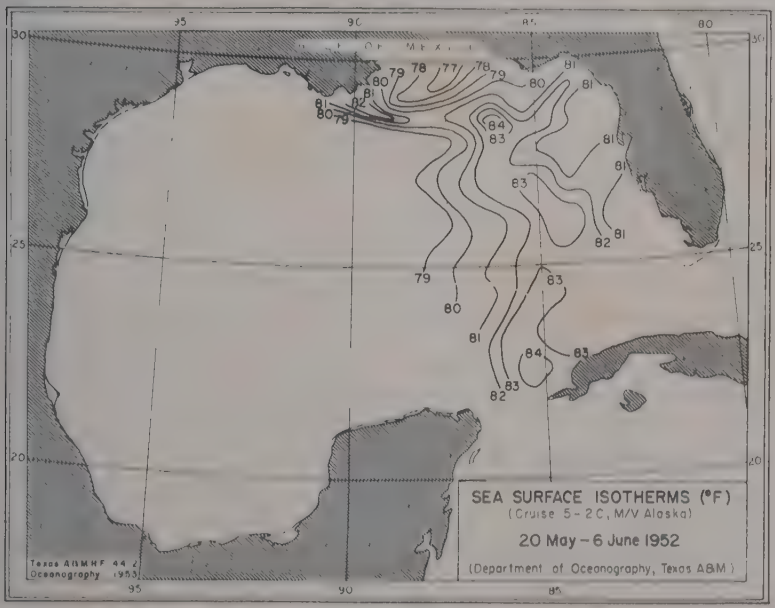
SEA SURFACE ISOTHERMS (°F)
(Cruise 5 – 2C, M/V Alaska)
20 May – 6 June 1952
(Department of Oceanography, Texas A&M)
Texas A&M RF 44-2
Oceanography 1953

FIGURE 2b

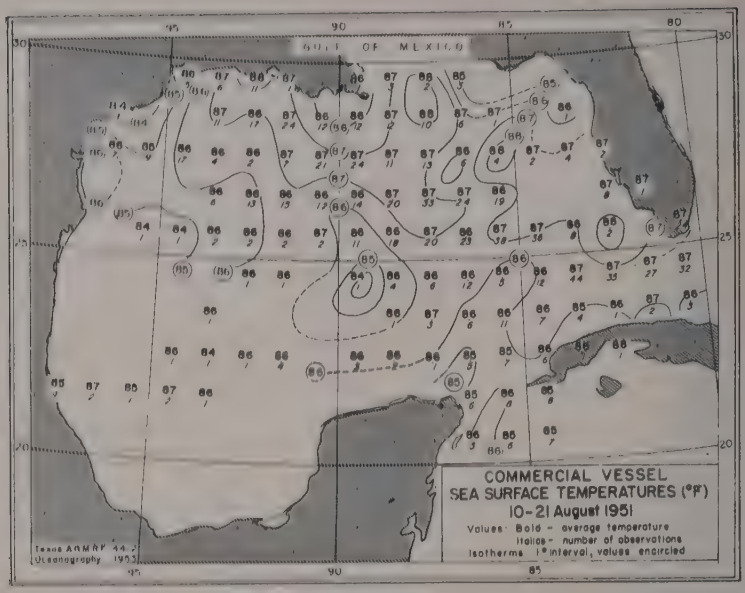

FIGURE 3a

FIGURE 3b

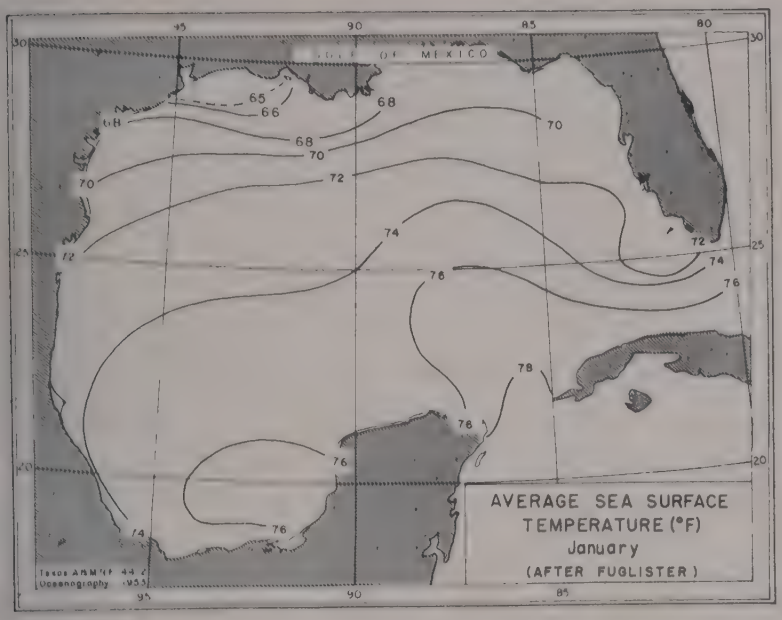

FIGURE 4

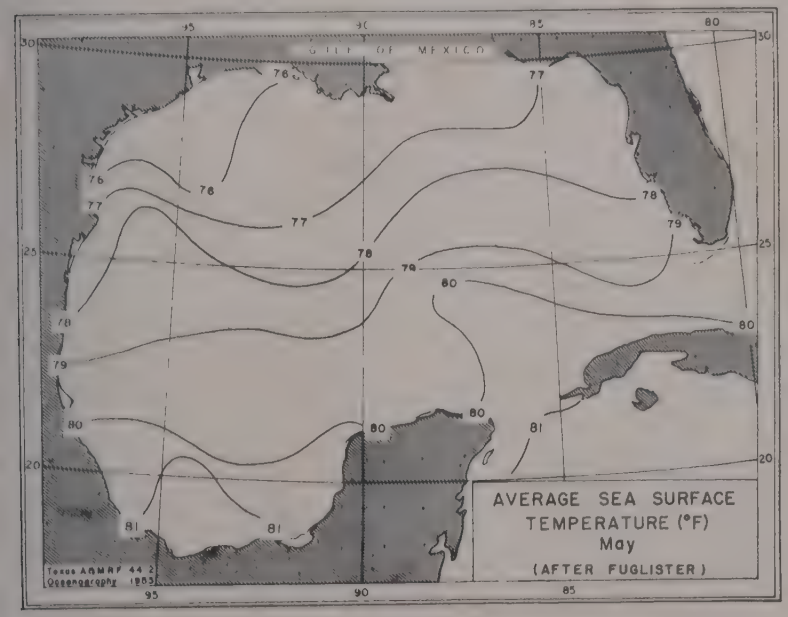

FIGURE 5

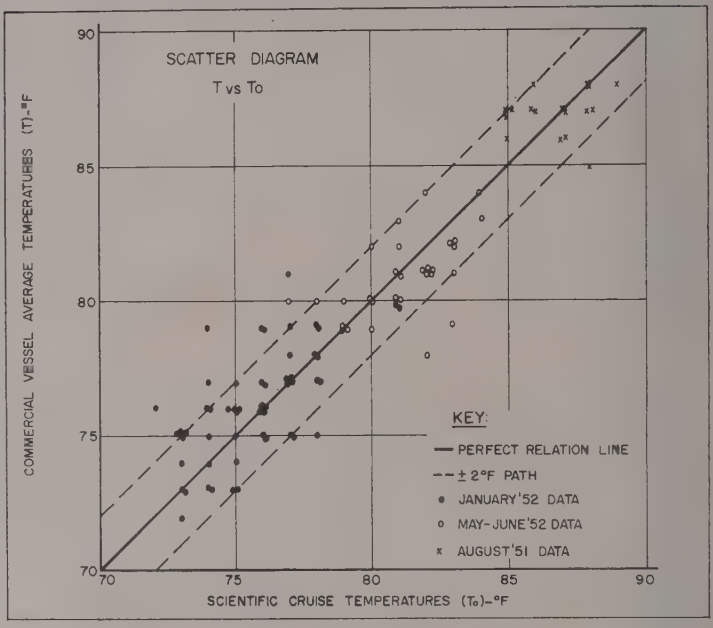

FIGURE 6

Inspection of the average sea surface temperature charts, Figures 4 and 5, reveals the loss of detail which is to be expected. The marked warm centers and east-west temperature gradients apparent on the short period charts are absent. It is probable these centers are always present, and that they vary in location as well as temperature. Consequently, long period averages would destroy these features.

The scatter diagram, Figure 6, shows the degree of association between the two sets of data. It is seen that 25 percent of the points fall on the perfect-relation line, while approximately 90 percent lie within the plus-or-minus (±) 2°F path. The standard error of estimate for the plot is 1.6°F with a correlation coefficient of 0.92.

Conclusion

The sea surface temperature distribution in the Gulf of Mexico as computed here from commercial vessel reports is seen to be nearly

identical to that derived from scientific oceanographic cruise data. Important features of this distribution which are of meteorological and oceanographic significance are retained in the three periods studied. Appreciable loss of critical detail is involved in mean monthly charts.

Based on the results of this study, it appears possible to determine the sea surface temperature pattern in the Gulf of Mexico by using short period averages of ship reports. This would furnish an effective tool for meteorological and oceanographic research in which this parameter is important. It would allow another degree of freedom in the choice of possible case studies made of the Gulf area.

Modification of air moving over the Gulf is in part dependent on the sea surface temperature distribution. Therefore, running short period averages could be compiled possibly on a day-to-day basis as data became available, and thus furnish an additional aid in Gulf coast forecasting.

This study was made in connection with work sponsored by the Geophysics Research Division of the Air Force Cambridge Research Center, under contract No. AF19(604)-169. The writer wishes to acknowledge the assistance given by George W. Reynolds and other members of Project 44, Department of Oceanography, A. and M. College of Texas.

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1934, 1935, 1936. Sea surface temperature summaries for various sections of the Gulf of Mexico. Mon. Weath. Rev., Wash. *62*, 1934; *63*, 1935;

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NOTES ON SOME CHAETOGNATHS FROM THE GULF OF MEXICO

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ABSTRACT

Four species of chaetognaths from the west coast of Florida were studied: *Sagitta hispida, S. helenae, S. tenuis* and *S. enflata. Sagitta hispida, S. helenae, S. tenuis* and *S. friderici* are figured and compared and *S. friderici* is redescribed. TC values of *S. tenuis* and *S. friderici* are given and it is concluded that the latter is a valid species. The confirmation of the presence of *S. hispida* and *S. tenuis* in the Atlantic greatly increases their known range.

I had the good fortune to examine some specimens of chaetognaths collected in the Gulf of Mexico about 15 miles off Ft. Myers Beach on January 21, 1949 by Dr. E. Lowe Pierce of the University of Florida, who asked me for my critical opinion on the identifications used in his paper (1951) which dealt with "The chaetognatha of the west coast of Florida." This material comprises several specimens of *Sagitta hispida, S. helenae, S. tenuis* and *S. enflata,* of which the last named species is cosmopolitan occurring commonly in the warm waters of the world, while the former three are reported only infrequently. The original descriptions of *S. hispida* and *S. tenuis* are so incomplete in various points that the two species have been treated as doubtful ones by some previous authors.

Pierce (1951) reviewed these species in his paper, and after careful comparison between his material and Conant's type specimens concluded:

a. *S. hispida* is a valid species occurring in the water of somewhat lower salinity along the coast of Florida.

b. *S. friderici* is synonymous with *S. tenuis* which name must be accepted as the specific name according to the law of priority.

Examining closely the specimens sent to me, I have come to the same conclusion as that of Pierce about the former item, but I am obliged to manifest here the opposite view about the latter one. Below, brief notes are given to complete the descriptions of these species, in addition to a close comparison between *S. tenuis* and *S. friderici*.

Sagitta hispida Conant, 1895

(Figures 1 and 2)

1895. Conant, F. S.: p. 290.

1941. Scaccini, A. and E. Ghirardelli: p. 8.

1951. Pierce, E. L.: p. 213.

The specimens at my disposal resemble closely *S. robusta* and *S. ferox* found in the Indo-Pacific. Rigid body, large head, existence of intestinal diverticula, corona ciliata of Type B and distinct collarette near the neck are all common to these three species. The anterior fin is shorter than the posterior and begins at the posterior end of the ventral ganglion; rayless zone absent, rays nearly vertical in the anterior third. More than half of the posterior fin lies on the caudal segment, broadest behind the septum; rayless zone absent, rays ver-

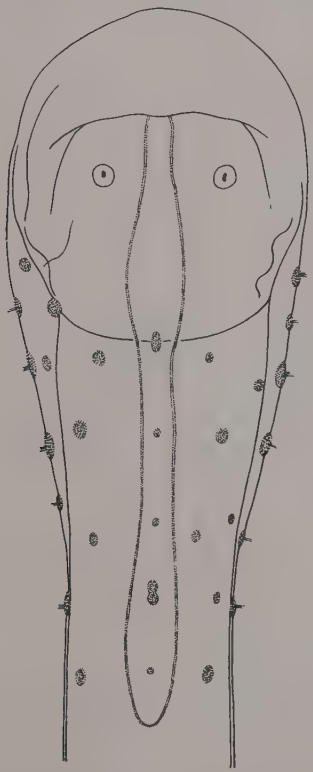

FIGURE 1. *Sagitta hispida* Conant. Anterior part of body, dorsal.

tical near the anterior end. The distance between the anterior and posterior fins is equal to the length of the ventral ganglion. Collarette extends to the middle or 2/3 of the distance between the neck and the anterior end of the ventral ganglion. Corona ciliata is nearly twice as long as the head, narrow and very slightly sinuous. Eye pigment is not dense, rather small, apparent shape elongate. Seminal vesicle situated just behind the posterior fin, separated by about half the length of the vesicle from the caudal fin; the shape like that of *S. robusta* or *S. bedoti*, often swells slightly at the antero-lateral corner and bursts along the lateral side. Ovary does not reach the middle of

Body length (mm)	*Caudal segment (%)*	*Hooks*	*Anterior teeth*	*Posterior teeth*
10	31	7-7	9-10	12-12
10.8	28	7-8	9-10	13-13
11	30	7-7	8- 8	12-13

Length measurements include the caudal fin.

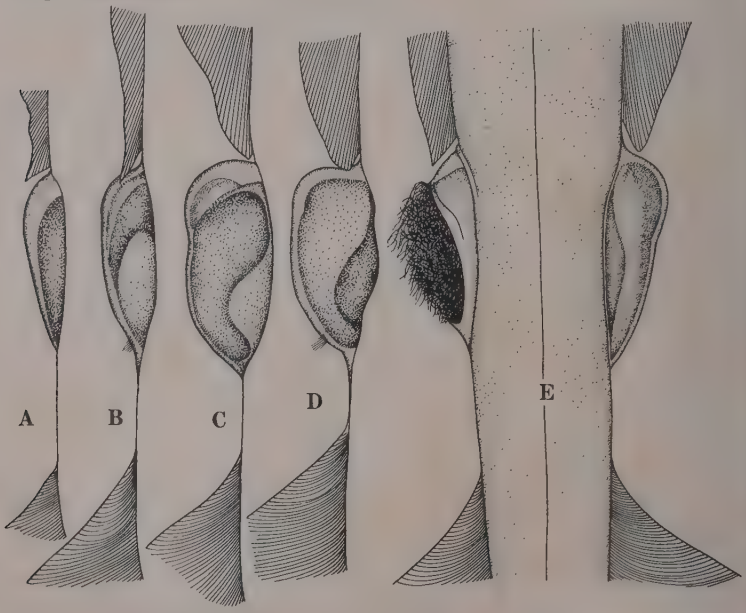

FIGURE 2. *Sagitta hispida* Conant. Seminal vesicles: A-C. Immature vesicles, D. Fully mature vesicle, E. Ruptured vesicle.

the anterior fin in my specimens, although it is described by Conant to reach the frontal end of the anterior fin.

Remarks: The shape or the situation of the seminal vesicle in *S. hispida* differs distinctly from those in *S. robusta* and *S. ferox*. The distance between the vesicle and the caudal fin is less than half the length of the vesicle in *S. robusta* and extremely small in *S. ferox*. A narrow rayless zone is discernible in the posterior fin near the septum in *S. ferox* and *S. robusta*. Front end of the anterior fin reaches the middle of the ganglion in *S. robusta*. Corona ciliata distinctly sinuous in *S. ferox*. In both Indo-Pacific species, eye pigment rather large and ovary reaches near the neck at maturity. Of these differences, only the characteristics about the seminal vesicle are reliable. I could hardly separate the species from one another if immature individuals of these three species were examined at the same time. Very fortunately, however, *S. hispida* is confined to the warm coastal waters along the eastern coast of the United States and the western coast of Africa (Rio de Oro), while *S. robusta* and *S. ferox* are in the warm oceanic waters of the Indo-Pacific.

Sagitta helenae Ritter-Zahony, 1910
(Figure 3)

1910. Ritter-Zahony, R.: p. 134.

1951. Pierce, E. L.: p. 218.

Body rigid, head large. Anterior fin shorter than the posterior and begins at the posterior end of the ventral ganglion; rayless zone absent, rays vertical near the frontal end. The portion of the posterior fin which lies on the caudal segment is slightly longer than the part on the trunk, broadest behind the septum; rayless zone absent, rays nearly vertical in the anterior third. Collarette distinct, extending from the neck to the middle of the distance between the neck and the ventral ganglion. Corona ciliata of Type B, about twice as long as the head, narrow and only slightly sinuous. Eye pigment rather large, apparent shape roughly oval. Intestinal diverticula absent. Ovary does not reach beyond the frontal end of the posterior fin in my specimens, although it is long in specimens observed by Ritter-Zahony. Seminal vesicle situated just behind the posterior fin, the distance between the vesicle and the caudal fin very small, ca. 1/7 of the length of vesicle. It is described as oval in outline at maturity, while it is a low and slender elevation in immature state, though the anterior portion is considerably swollen.

Body length (mm)	*Caudal segment (%)*	*Hooks*	*Anterior teeth*	*Posterior teeth*
11.1	28	8-8	12-12	11-12
11.6	29	8-8	8- 9	12-12
13.6	26	7-8	16-17	12-13

Rows of anterior teeth meet with each other in an obtuse angle.

Remarks: This species has hitherto been recorded only from the water of rather high salinity along the coast of Florida. The situation of the seminal vesicle in mature individuals, the arrangement of numerous anterior teeth and the absence of intestinal diverticula are

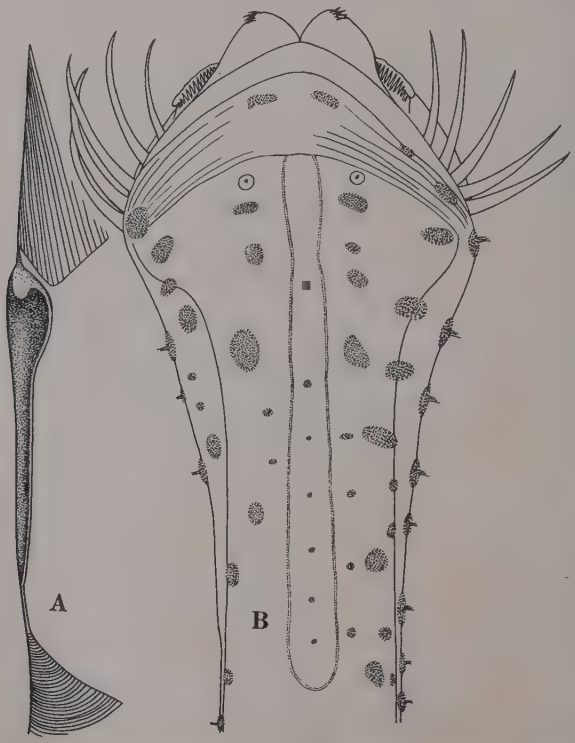

FIGURE 3. *Sagitta helenae* Ritter-Zahony. A. Seminal vesicle, B. Anterior part of body, dorsal.

the characteristics differentiating the present species from *S. hispida*, which are otherwise similar in appearance.

Sagitta tenuis Conant, 1896
(Figure 4)

1896. Conant, F. S.: p. 213.
1911. Ritter-Zahony, R. *S. friderici*: p. 19.
1923. Gray, B. B. *S. setosa*: p. 173.
1941. Scaccini, A. and E. Ghirardelli: p. 6.
1951. Pierce, E. L.: p. 219.
1952. Faure, M. L.: p. 26.
1952. Fraser, J. H.: p. 13.

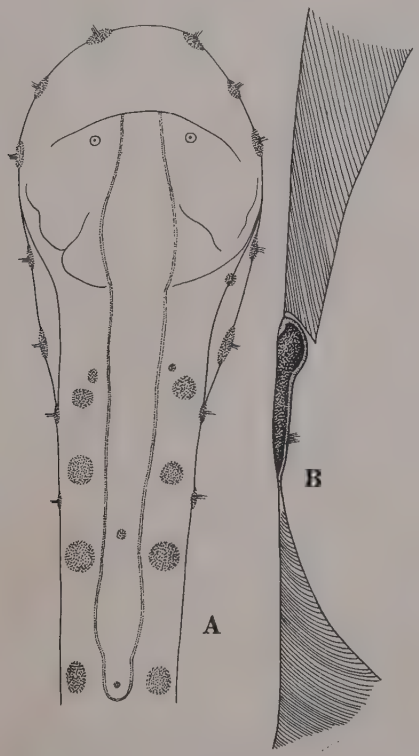

FIGURE 4. *Sagitta tenuis* Conant. A. Anterior part of body, dorsal, B. Seminal vesicle.

1952. Vannucci, M. and K. Hosoe: p. 14.
1953. Furnestin, M. L.: p. 412.

The frontal end of the anterior fin falls posterior to the ventral ganglion in my specimens. This feature is, however, attributable to the imperfect condition of preservation of fins. Posterior fin longer than the anterior, ca. 2/3, lies on the caudal segment and broadest behind the septum; rays vertical near the frontal end. Distance between the anterior and posterior fins somewhat large. Thin collarette near the neck, extending over a distance as long as the head. Corona ciliata about 2½ times the head length. Eye pigment small, apparent shape roundish. Intestinal diverticula absent. Ovary does not reach beyond the frontal end of the posterior fin in my specimens, 4.5—8.6% (5.9% on the average of 12 individuals) of the body length. Seminal vesicle in contact with both posterior and caudal fins; it is rather narrow and with somewhat swollen anterior end.

Body length (mm)	*Caudal segment (%)*	*Hooks*	*Anterior teeth*	*Posterior teeth*
7.6	28	8-8	6-7	16-17
8	28	9-9	6-7	16-17
8.2	29	7-7	6-7	13-14

Remarks: Faure (1952) insists that *S. friderici* is not identical with *S. tenuis* chiefly on account of the differences found in the body length of mature individuals and the armament formula for the same body length. For instance, she shows the formula 6-7 $\frac{4\text{-}5}{6\text{-}8}$ for 7 mm long individuals from the waters of Morocco against that, given by Pierce, 6-7 $\frac{6\text{-}7}{18\text{-}19}$ for 7 mm long individuals from the waters of Florida. At first, I was of the opinion that *S. friderici* is identical with *S. tenuis* for the following reasons. My 8.2 mm long individual shows the formula 7-7 $\frac{6\text{-}7}{13\text{-}14}$ and this is very like that 6-7 $\frac{5\text{-}6}{8\text{-}13}$ for 8 mm long individuals from the waters of Morocco (Faure, 1952). Moreover, Scaccini and Ghirardelli (1941) show the formula 7-8 $\frac{6\text{-}8}{14\text{-}20}$ for 7-10 mm long individuals collected from the waters off Rio de Oro, the formula 8-8 $\frac{7\text{-}7}{12\text{-}12}$ for 8.2-8.5 mm long individuals from the waters near Trinidad (Vannucci and Hosoe, 1952) and that 6-8

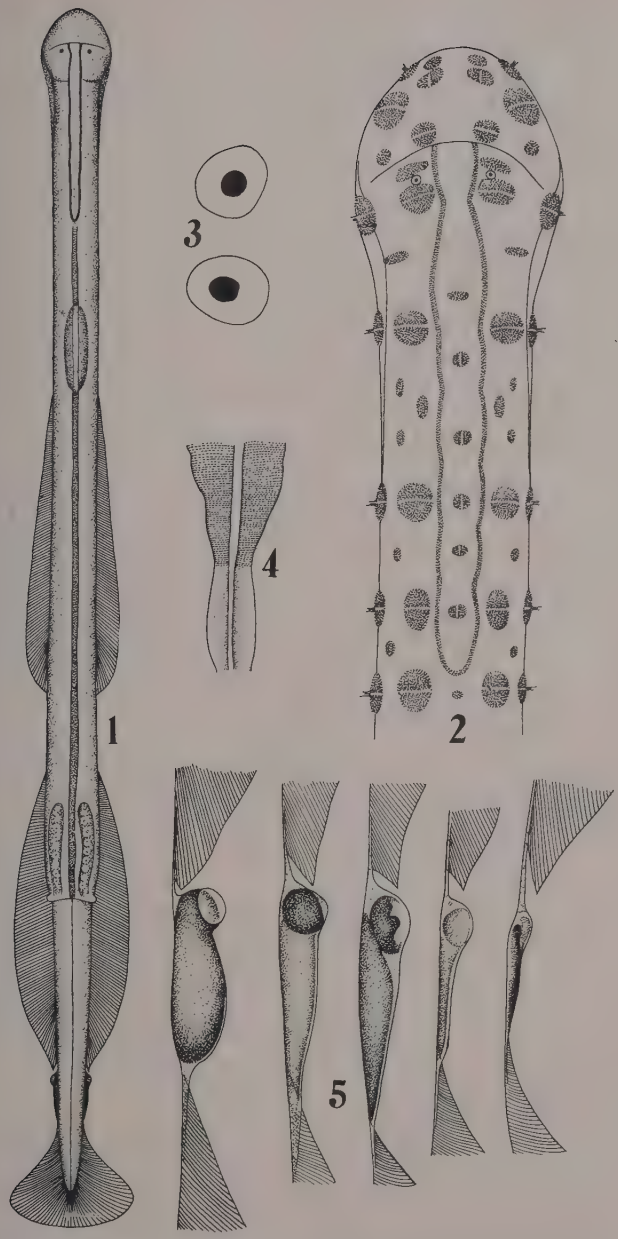

FIGURE 5. *Sagitta friderici* Ritter-Zahony. 1. Entire animal, dorsal view, 2. Anterior part of trunk, dorsal, 3. Eye, 4. Anterior end of intestine, 5. Seminal vesicles in various stages of development.

$\frac{4\text{-}8}{8\text{-}14}$ for 4.2-10.2 mm long individuals from the coastal waters of Israel (Furnestin, 1953) are very like that of my 8.2 mm long individual. All these formulae are considered to be in the range of variations occurring in one species, although the range seems rather wide. The body length of mature individuals may greatly differ locally or in populations as shown clearly in some other species. For instance, *S. robusta* matures fully at 8 mm in the tropical Pacific (Tokioka, 1942), while it reaches 21 mm in the Sea of Japan (Tokioka, 1940); *S. bedoti* reaches nearly 30 mm in the Sea of Japan (Tokioka, 1940), while it matures at 11 mm in the tropical Pacific (Tokioka, 1942). The hooks and teeth may increase in number as it approaches maturity. Consequently small mature individuals are often provided with more hooks and teeth than those of the same body length which are not yet mature. Thus, I sent to Dr. E. L. Pierce a manuscript with the opinion that *S. friderici* is identical with *S. tenuis*.

However, I was informed by Dr. E. L. Pierce that Fraser manifested also the opposite view regarding synonymy of *S. friderici* with *S. tenuis*. Indeed, I overlooked Fraser's paper of 1952. He says on p. 14, "Owing to the marked size difference (Pierce's largest specimen is 8 mm), and the *somewhat different general appearance* (Plate II, Figs. 12 and 13) it would seem advisable to retain the validity of both species at least until more work on their biology has been completed." This underlined statement on the existence of differences in general appearance is considered to be a grave matter. Immediately I became aware of the necessity of examining some specimens of *S. friderici* and asked Mme. M. L. Furnestin in Casablanca to give me a chance to examine some specimens from the waters of Morocco. Very happily I could get a lot of specimens of *S. friderici* and examine them carefully. For convenience in comparing *S. tenuis* easily with *S. friderici*, I give briefly the description of the latter (Figure 5).

Body robust, slightly translucent and does not show the hispid appearance. Caudal segment 26.9-30.3% in 7.3-9.8 mm long individuals and 24.4-28.9% in 10.7-11.6 mm long individuals. Head of moderate size, neck rather distinct, short collarette around the neck. Slight constriction at tail septum. Anterior fin begins at the posterior end of the ventral ganglion. Posterior fin longer than anterior fin, $\frac{\text{ant. fin}}{\text{post. fin}} \times 100 = 71.9\text{-}104.6$ (86.8 on the average of 9 individuals) and lies more on the tail segment than on the trunk, and broad-

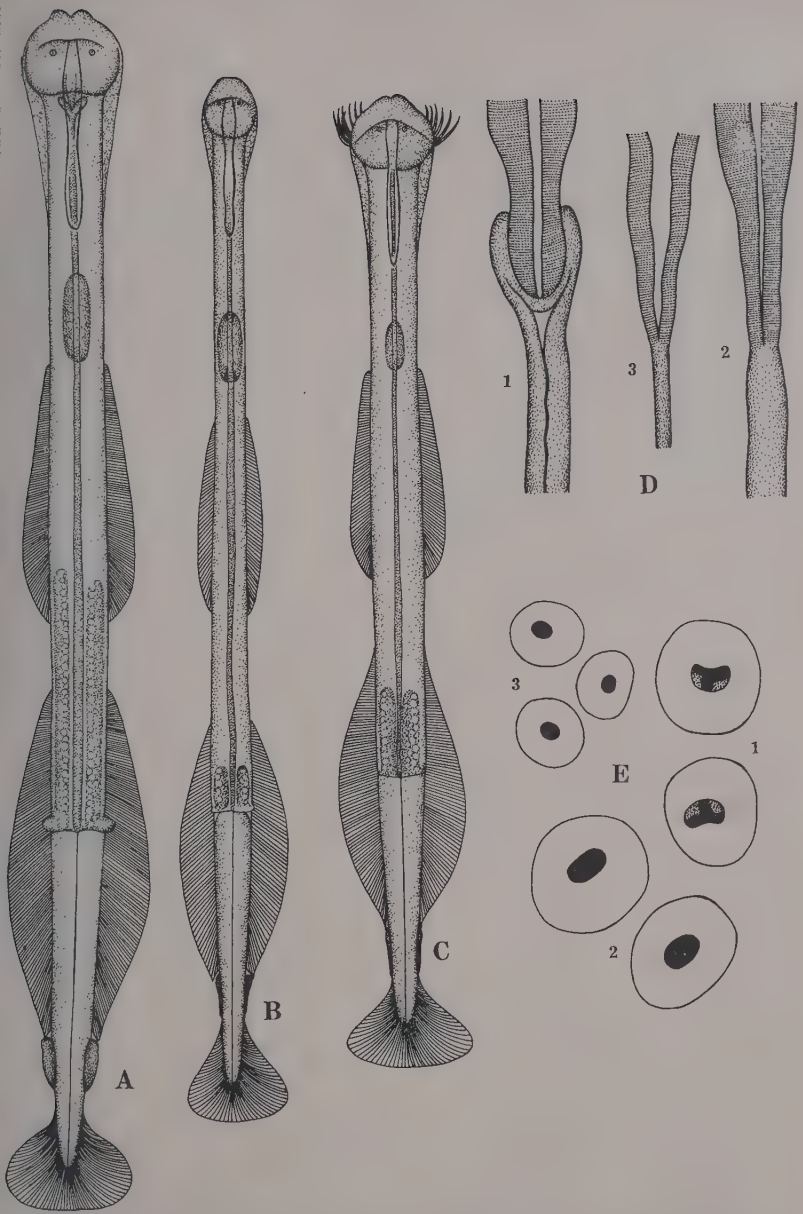

FIGURE 6. A. *Sagitta hispida* Conant, B. *S. tenuis* Conant, C. *S. helenae* Ritter-Zahony, D. Anterior end of intestine: 1. *S. hispida,* 2. *S. helenae,* 3. *S. tenuis.* E. Eye pigments: 1. *S. hispida,* 2. *S. helenae,* 3. *S. tenuis.*

est behind the septum. Distance between both fins shows a wide range of variation, 12.7-31.8% (24.6 on the average of 8 examined individuals) of the posterior fin. Rayless zone absent on either fin. The apparent shape of eye-pigment comparatively large, 27-40% (36.5 on the average of 13 eyes) of the eye in diameter. Corona ciliata of Type B, slightly longer than twice the head length and has a pair of sinuses behind the eyes. Intestinal diverticula absent. Armament formula 7-9 $\frac{5\text{-}6}{11\text{-}14}$ for 7.3-9.8 mm long individuals and 7-9 $\frac{6\text{-}7}{14\text{-}17}$ for 10.7-11.6 mm long individuals. Rows of anterior teeth meet in an acute angle. Ovary short, 4.3-8.0% of the body length in 7.3-9.8 mm long individuals and 5.7-11.8% in 10.7-11.6 mm long individuals. Seminal vesicle of *ferox*-type, consisting of distinct head and trunk, and in contact with both posterior and caudal fins.

The body size of the mature individuals differs distinctly, anterior

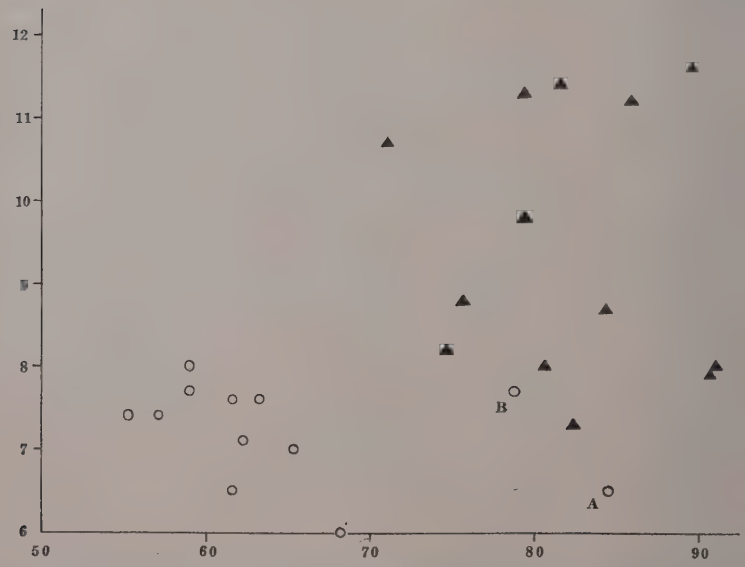

FIGURE 7. TC values of *Sagitta tenuis* and *S. friderici*. 0 - *S. tenuis*, Δ - *S. friderici*. Long. axis- Body length in mm, Trans. axis - TC values.

and posterior teeth mostly show some differences in number for 5-8 mm long individuals between the two species. I can not, however, appreciate these differences as being of specific importance, as mentioned already (Figure 6). The length of mature ovaries is longer in *S. friderici* than in *S. tenuis*. This difference also can not be considered of essential nature, when mature individuals differ in size between the two species. The appearance of the seminal vesicle of *S. tenuis* described here does not differ essentially from that of *S. friderici* in earlier stages of development. Comparing specimens of both species carefully and figures of both species given by previous authors in detail, I have been aware of the differences found in the ratio between the anterior and posterior parts of the posterior fin in these species (Figure 7). The values (TC)

$$\frac{\text{anterior part of the posterior fin along the trunk}}{\text{posterior part of the posterior fin along the caudal segment}} \times 100$$

in each species are tabulated below:

	Sagitta tenuis			*Sagitta friderici*		
	Body length (mm)	Caudal segment %	TC	Body length (mm)	Caudal segment %	TC
	6.0	29.9	68.3	7.3	27.8	82.4
	6.5	30.0	61.6	7.9	28.6	90.7
A	6.5	26.7	84.5	8.0	28.3	91.0
	7.0	28.6	65.3	8.0	30.1	80.7
	7.1	—	62.3	8.2	30.3	74.7
	7.4	31.2	55.3	8.7	29.5	84.4
	7.4	28.8	57.1	8.8	28.1	75.6
	7.6	28.7	63.3	9.8	29.3	79.4
	7.6	32.2	61.6	10.7	28.9	71.1
	7.7	29.8	59.0	11.2	24.4	85.8
B	7.7	27.5	78.8	11.3	25.3	79.4
	8.0	30.3	59.0	11.4	26.0	81.6
				11.6	25.5	89.6

The difference of the TC-value between two species may be safely considered to be of essential nature. The value in *S. tenuis* shows two exceptional cases at A and B. In these two individuals, however, the caudal segment is comparatively short. This fact alludes to the possibility that the two exceptional values occurred artificially by the contraction of the caudal segment.

The rather translucent appearance of *S. friderici* and somewhat hispid appearance of *S. tenuis* may be accepted as specific differences, although they are too delicate to be applied practically on identifica-

tion. So far as the present material is concerned, the appearance of the corona ciliata seems to differ between the two species: the corona has a pair of sinuses just behind the eyes in *S. friderici,* but lacks them in *S. tenuis.* The ratio of the length of the anterior fin to that of the posterior fin may possibly be a significant characteristic, if it is measured on perfectly preserved specimens which are not contracted laterally.

Thus my first idea was upset by the examination of specimens of *S. friderici* and now I am converted to the opinion supported by Fraser and Faure. There remains still in my mind the following idea that *S. friderici* may possibly occur also in the waters of the West Indies in small numbers and we are not yet able to separate it from *S. tenuis.* I can not definitely deny the possibility that individuals A and B in *S. tenuis,* showing high TC-values, and the 8.2 mm long individual of *S. tenuis* having fewer (13-14) posterior teeth may be immature individuals of *S. friderici.* More crucial analytical studies are desirable on abundant specimens of *S. tenuis.*

The chaetognath fauna of the Atlantic was increased by the confirmation of *S. hispida* and *S. tenuis.* As to *Pterosagitta besnardi* reported by Vannucci and Hosoe (1952) from the waters near Trinidad, the characteristics differentiating this species from *P. draco* seem to be in the range of individual variations in one species. *S. setosa* reported by Gray (1923) from the waters off the coast of West Africa at 15° N is probably *S. friderici.*

Lastly I express my hearty thanks to Dr. E. L. Pierce and Mme. M. L. Furnestin for their kindness in giving me the chance to examine specimens of exotic species and for their useful advice.

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THE TAXONOMIC STATUS OF THE FISHES OF THE GENUS *STATHMONOTUS*, INCLUDING A REVIEW OF THE ATLANTIC SPECIES

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Abstract

The genus *Auchenistius* is synonymized with the genus *Stathmonotus*. *Stathmonotus* is included in the family Clinidae. Errors in the literature pertaining to the classification of the Clinidae and Blenniidae are discussed. A key is given to all the species of *Stathmonotus* and the Atlantic forms are reviewed. *Stathmonotus gymnodermis* n. sp. is described.

Introduction

In the course of studying various blennioid fishes, certain facts became evident which showed that some of the more recent studies concerning this group were in error or incomplete. Inasmuch as this group of fishes is at present receiving an increasing amount of attention, it was felt that these errors should be corrected and the new information presented in order to prevent future misinterpretations.

Numerous individuals have aided in making this paper possible. I wish to express my thanks to the officials of the U.S. National Museum and especially Dr. Leonard P. Schultz, Curator of Fishes, for their hospitality during my period of study at the Division of Fishes and for permission to describe the new species. Dr. John T. Nichols gave information concerning his type *Stathmonotus tekla*. Dr. Boyd W. Walker lent specimens of *Stathmonotus sinus-californici*. Mr. Norman J. Wilimovsky gave information concerning the type of *Stathmonotus culebrai*. Dr. Clark Hubbs lent specimens of *Exerpes asper* and offered valuable suggestions during the course of the work. Sincere appreciation is due Mr. Gilbert Voss and Mr. Luis R. Rivas for their valuable criticisms and suggestions during the preparation of the manuscript.

Systematic Discussion

An undescribed species of blennioid fish was discovered in the collections of the U.S. National Museum. The morphology of this

species resembles the body form attributed to *Stathmonotus* Bean, which Hubbs (1953a) placed in the tribe Stathmonotidi (family Blenniidae, subfamily Chaenopsinae). It also bore a close resemblance to *Auchenistius* Evermann and Marsh, which Hubbs (1952) placed in the tribe Paraclinidi (family Clinidae, subfamily Labrisominae) along with *Paraclinus* and *Exerpes*. The new species seems to form a link between the currently recognized genera *Auchenistius* and *Stathmonotus*. A study of the species of *Stathmonotus,* and *Auchenistius stahli* (*Auchenistius* is now considered monotypic), shows that these fishes form a compact, natural group which can be included under a single genus, *Stathmonotus*.

The presence of cirri in *Stathmonotus* is a variable character and, accordingly, Böhlke (1953) considered it only of specific importance. The only other difference between *Auchenistius* and *Stathmonotus* is the presence of scales. In view of the many characters (Table I) in common with the rest of the group and the new species in particular, *Auchenistius* is considered to merit subgeneric rank only. (See also p. 73).

Stathmonotus hemphilli, the type species, does not have scales or head cirri. *S.* (*Auchenistius*) *stahli* is scaled and has cirri on the tube of the anterior nostril, above the eye, on the nape, and on the preopercle. The new species has the same disposition of cirri as *stahli,* but it has no scales. None of the Pacific species have scales, but *S. lugubris* has cirri above the eye and on the tube of the anterior nostril. *S. sinus-californici* has cirri above the eye only. *S. culebrai* has no cirri.

Nichols (1910) was the first to notice the relationship between *Auchenistius* and *Stathmonotus* although he never called attention to it as such. He described as a new species *S. tekla,* which Longley and Hildebrand (1941) placed in synonymy with *A. stahli*. I believe Nichols' species to be a distinct subspecies of *S. stahli,* as explained in the discussion of that species.

In the course of the study of *Auchenistius,* certain discrepancies called to my attention the fact that the tribe Paraclinidi was in need of further study. Hubbs' basis of separation of the Paraclinidi from other clinid tribes was the presence of an opercular spine, less than three dorsal soft rays, and usually 13 pectoral rays. These characters well defined *Paraclinus* and *Exerpes,* but not *Auchenistius,* of which Hubbs examined no specimens (Personal communication, 1953).

Study of 41 specimens of *S.* (*Auchenistius*) *stahli,* including the

TABLE 1.
COMPARISON OF THE SPECIES OF *Stathmonotus*

Character	*stahli*	*gymnodermis*	*hemphilli*	*lugubris**	*sinus-californici*	*culebrai*
1. Scales	Present	Absent	Absent	Absent	Absent	Absent
2. Vestigial lateral line pores	Present	Present	Present	Present	Present	Present
3. Vomerine teeth	Present	Present	Present	Absent	Absent	Absent
4. Conical teeth in jaws	Present	Present	Present	Present	Present	Present
5. Supraorbital cirri	Present	Present	Absent	Present	Present	Absent
6. Nuchal and preopercular cirri	Present	Present	Absent	Absent	Absent	Absent
7. Nasal cirri	Present	Present	Absent	Present	Absent	Absent
8. Lachrymal reaching to beneath middle of orbit	Yes	No data	Yes	No data	Yes	No data
9. Preopercle without free edge	Yes	Yes	Yes	Yes	Yes	Yes
10. Male with swollen head and extended maxillaries	Yes	Yes	No data	Yes	Yes	No data
11. Dorsal spines	41-44	42-44	47-53	37-38	40-45	39-42*
12. Anal rays	II,22-25	II,21-25	II,23-29	II,20-22	II,22-26	II,24
13. Pectoral rays	6-9	8-9	3-6	10	7-10	10
14. Pelvic rays	I,2	I,2	I,2	I,2	I,2	I,2
15. Articulated caudal rays	10-12	11	10-13	11-12	12-14	12

*After Böhlke (1953)

holotype, from various localities disclosed that an opercular spine was rarely present. The pectoral rays were found to range from 6-9 with 8 being the most frequent number. Hubbs (1952) as well as Evermann and Marsh (1899) was in error in describing *S. stahli* as having no lateral line pores. The pores are present, but are rudimentary (consisting of a small depression in the middle of the scale) and not visible when there is a surplus of liquid on the specimen. They begin over the base of the pectoral and continue in a straight line to a point over the tip of the pectoral where they descend abruptly to the middle of the body and continue backward in a straight line almost to the base of the caudal.

In his separation of the tribe Stathmonotidi from other blenniid tribes, Hubbs (1953a) based his concept on *Parastathmonotus sinuscalifornici* Chabanaud. (Personal communication, 1953). *P. sinuscalifornici* differs from *S. hemphilli* in having supraocular cirri, which is the main character Hubbs used in separating the tribe Stathmonotidi from others of the subfamily Chaenopsinae. Böhlke (1953) has since synonymized *Parastathmonotus* with *Stathmonotus*. He has also shown that previous authors (Chabanaud, 1942; Jordan and Evermann, 1898; Bean, 1885; and Beebe and Tee-Van, 1928) were in error in describing species of *Stathmonotus* as not having lateral line pores.

The close relationship shown by the members of the genus *Stathmonotus*, which in the literature are contained in two families, raises the problem as to which of the families is the proper one for their inclusion. Hubbs (1952), following Regan (1912), separated the Blenniidae from the Clinidae by the following key:

> Suborbital ring weak; lachrymal expanded anteriorly but not extending to middle of eye; other 3 suborbitals weak, deeper than wide; scales present, imbricate or not. Clinidae
>
> Suborbital ring stout; lachrymal expanded posteriorly to point below middle of eye or farther; other 3 suborbitals stout, wider than deep, scales absent except in *Neoclinus* which has small, nonimbricate scales. Blenniidae

Hubbs, (1952) based his characterization of the lachrymals of these two families on skeletal material consisting of eight genera and nine species representing both families. Although none of the species studied by Hubbs were available for dissection, several of the genera

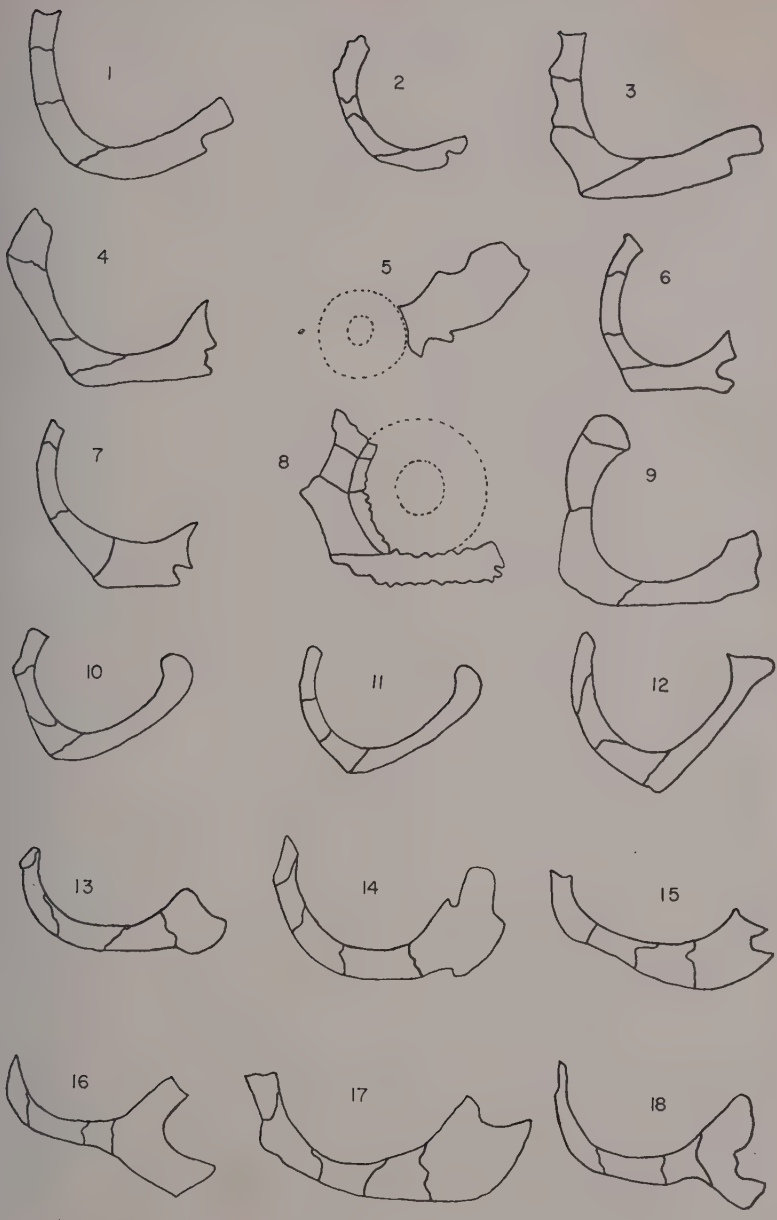
were, and upon request he sent a drawing of the suborbitals of *Paraclinus integripinnis* (Figure 1, 2), a species included in his study. Examination of the suborbitals of the genera available disclosed that Hubbs was in error in his considerations on lachrymals. The characters concerning the suborbitals appear to have been switched in the two families. It was found that in the Clinidae the suborbitals are usually somewhat stouter than those of the Blenniidae, though not much more so. The lachrymal in the Clinidae of Hubbs (1952, excepting *Exerpes*) is extended posteriorly to a point below or beyond the middle of the ventral margin of the orbit (Figure 1, 1-4, 6, 7). The species studied included the following: *Labrisomus nuchipinnis, L. kalisherae, Malacoctenus macropus, Paraclinus fasciatus,* and *P. marmoratus*. Hubbs' drawing of the suborbitals of *P. integripinnis* supported the above findings. Günther (1861) wrote that the suborbitals of *L. nuchipinnis* were stout, but that the sutures between the bones were absent. I find the sutures present in all specimens thus far examined.

In *Exerpes asper* (Figure 1, 5) a unique condition was found to exist. There is but one suborbital, the lachrymal, which is greatly expanded anteriorly, but reaches posteriorly only to the anterior margin of the orbit. The ventral margin of the orbit in this species is bounded only by muscle and skin.

In both the Clinidae and Blenniidae the character of the remaining suborbitals as regards length and width was not found to be consistent. The presence of scales in the Clinidae is also not a consistent. character. *Clinoporus* Barnard, which is considered by most authors as a clinid, has none.

The suborbitals of the Blenniidae (except *Runula*) were found to differ from those of the Clinidae in that the lachrymal never extended posteriorly to beneath the middle of the orbit (Figure 1, 13-18). The species studied were: *Blennius cristatus, Hypsoblennius ionthas, Hypleurochilus geminatus, Entomacrodus textilis, Chasmodes bosquianus,* and *Scartichthys atlanticus*. *Blennius, Chasmodes,* and

FIGURE 1. Semidiagrammatic drawings of the suborbital bones of certain Blennioid fishes. 1, *Paraclinus marmoratus;* 2, *Paraclinus integripinnis;* 3, *Paraclinus fasciatus;* 4, *Labrisomus nuchipinnis;* 5, *Exerpes asper* (position of eye indicated); 6, *Labrisomus kalisherae;* 7, *Malacoctenus macropus;* 8, *Acanthemblemaria spinosa* (position of eye indicated); 9, *Runula azalea;* 10, *Stathmonotus hemphilli;* 11, *Stathmonotus stahli;* 12, *Stathmonotus sinus-californici;* 13, *Blennius cristatus;* 14, *Chasmodes bosquianus;* 15, *Hypleurochilus geminatus;* 16, *Entomacrodus textilis;* 17, *Hypsoblennius ionthas;* 18, *Scartichthys atlanticus*.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Hypsoblennius were found to have five suborbitals; one more than Hubbs (1952) found for any of the members of his superfamily Blenniicae, which includes the two families under discussion.

Runula (Figure 1, 9) was placed by Jordan (1923) in a separate family, Runulidae. Berg (1940) included the Runulidae in his family Blenniidae. Norman (1943) considered *Runula* as synonymous with *Aspidontus* and included it in his subfamily Blenniinae, in which, however, he said it formed a distinct group. Schultz (1950) re-erected *Runula* and placed in synonymy with it *Atopclinus* which Jordan, Evermann, and Clark (1930) had considered a member of a distinct family, Atopclinidae. *Runula* was placed by Schultz in a subfamily, Petroscirtinae, which he evidently considered in the Blenniidae. From a study of a few specimens of *Runula* and many representatives of other blennioid genera, it is my opinion that this genus could be considered a member of a distinct family; however, until more species are studied, I retain *Runula* in the Blenniidae. In contrast to other blenniids it has the extended lachrymal as found in the clinids. It also differs from other blenniids in having both jaws inferior rather than terminal; in having the upper jaw anterior to rather than dorsal to the lower jaw; in having the teeth in the upper jaw twice the size of those in lower jaw rather than about the same size; and in having the caudal fin forked in the adult rather than rounded or truncate.

In his revision of *Neoclinus,* Hubbs (1953a) considered the Chaenopsinae as a subfamily of the Blenniidae mainly because of the posterior extension of the lachrymal to beyond a point below the middle of the orbit, thus following his earlier error. The lachrymals of *Acanthemblemaria* (*A. spinosa*: Figure 1, 8) and *Stathmonotus* (*S. stahli, S. hemphilli, S. sinus-californici*: Figure 1, 10-12) which are included in this subfamily, do extend posteriorly in the manner which Hubbs described. The suborbitals of *Acanthemblemaria* are comparatively stout and even armed with spines, while those of *Stathmonotus* are quite slender. On the basis of the lachrymal the subfamily Chaenopsinae of Hubbs shows a closer relationship to the Clinidae than the Blenniidae. This relationship is further indicated when one considers that the conical and villiform teeth of the Chaenopsinae are found in the Clinidae, but not in the Blenniidae. Another strong argument in favor of this relationship is the type of sexual dimorphism found in *Neoclinus* and *Stathmonotus,* involving the

greatly increased size of the maxillary in adult males (Hubbs, 1953a; Böhlke, 1953) which has its parallel in the genus *Paraclinus* (Hubbs, 1952) and to some extent *Labrisomus* (Hubbs, 1953b). This type sexual dimorphism has not been demonstrated in any of the Blenniidae, where sexual dimorphism, if it occurs, usually involves the presence of anal papillae in the females and the formation of fleshy tufts around the anal spines in the males. These modifications are not of the same type as those involving the anal spines of the clinid genus *Brannerella* which has the first anal spine of the male greatly elongated with a tube attached to it. The dorsal fin of *Stathmonotus,* composed entirely of spines, also finds a parallel in certain species of *Paraclinus,* but in none of the Blenniidae, in which there are also dorsal soft rays. *Stathmonotus* is similar to the Blenniidae, so far as I am able to determine, only in that the preopercle has no free edge along any portion of its length.

It is believed by the author on the basis of the structure of the lachrymal, the type sexual dimorphism, and the type of dentition that the Chaenopsinae are clinids. I also consider that they do not form an entirely natural group. *Stathmonotus* appears to be a direct offshoot of the Paraclinidi for reasons mentioned above. It is retained in this tribe where Hubbs (1952) listed its synonym, *Auchenistius.*

The point whence *Neoclinus* arose is not known, but based on the similarity of the sexual dimorphism, it was most probably derived from an earlier group which later gave rise to the Paraclinidi. The emblemariids appear to have been derived from a *Neoclinus*-like ancestor despite their lack of a lateral line and scales. They resemble *Neoclinus* in general body form and especially in the flexible spines of the dorsal, the dentition, and cirri. No specimens of the Chaenopsidi were examined.

Due to the confusion in the literature as regards the Clinidae and Blenniidae, the following key is presented in the hope that it will aid in the recognition of these two families.

Conical or villiform teeth present in jaws and sometimes on vomer and palatines. Scales usually present. Lachrymal expanded posteriorly to a point below middle of eye or farther (except *Exerpes*). Preopercular margin usually free for part of its length. Premaxillaries protractile. Gill membranes united, always free from the isthmus. Clinidae

Jaws with a series of slender, close-set teeth resembling the teeth of a comb; sometimes with a few enlarged canines posteriorly; sometimes a few teeth on vomer, none on palatines. Body always without scales. Lachrymal not expanded posteriorly to a point below middle of eye

(except *Runula*). Preopercular margin not free for any portion of its length. Premaxillaries not protractile. Gill membranes united, free or fused with the isthmus. Blenniidae

Review of the Atlantic Species of *Stathmonotus*

Stathmonotus Bean

Stathmonotus Bean, 1885: 191 (type species by monotypy *S. hemphilli* Bean).

Auchenistius Evermann and Marsh, 1899: 359 (type species by monotypy *A. stahli* Evermann and Marsh; here retained for a subgenus).

Histioclinus Metzelaar, 1919: 157 (type species by monotypy *H. veliger* Metzelaar [*S. stahli*]).

Parastathmonotus Chabanaud, 1942: 115 (type species by original designation *Parastathmonotus sinus-californici;* here retained for a subgenus).

Elongate, tropical or subtropical blennies with a dorsal fin composed entirely of numerous (37-53) short, stout spines. Anal fin with two spines and numerous (20-28) soft rays. Pelvics with one spine (usually visible only after dissection or staining) and two rays. Pectorals with 3-10 rays; caudal with 10-14 articulated rays. All rays unbranched. Branchiostegals 6 (Bean, 1885, incorrectly listed the types of *S. hemphilli* as having 5 branchiostegals).

Conical teeth on mandibles and premaxillaries in two rows anteriorly, merging into one row posteriorly. Small teeth sometimes present on vomer, none on palatines.

Anterior nostril with a short tube which may or may not bear a simple cirrus on its posterior margin. A broad, rounded cirrus sometimes present above each eye. A smaller cirrus sometimes present on each side of the nuchal region. Preopercle covered by a membrane; its posterior margin visible externally only as a series of pores, one of which may have a cirrus. Scales present or not. Lateral line composed of rudimentary pores, some of which may be double. Orbit bounded by four slender bones, the first of which extends posteriorly at least to a point beneath the middle of the orbit.

Sexual dimorphism present. Mature males have longer, more expanded maxillaries than the females, and also swollen heads.

Distribution: eastern Pacific from Costa Rica, Mexico, and the Gulf of California; western Atlantic from southern Florida, Bahamas, Greater and Lesser Antilles, Bonaire Island, and Old Providence

Island.

The genus *Stathmonotus* differs from its closest relative, *Paraclinus,* in having its lateral line composed entirely of rudimentary pores; in having the free edge of the preopercle covered by a membrane for its entire length; in not always having an opercular spine; in having fewer pectoral rays; and in having some species without scales.

Böhlke (1953) has recently described a new species of *Stathmonotus* and presented an artificial key to the species. The following key, based in part on his work, is presented in an effort to express the natural relationships of the group. I recognize three subgenera: *Parastathmonotus,* which includes all the Pacific species and is recognizable by the absence of vomerine teeth; *Auchenistius,* which refers to those Atlantic species with head cirri; and *Stathmonotus,* which refers to that Atlantic species without head cirri. The Pacific species, well reviewed by Böhlke (1953), are not discussed in this paper.

The specimens personally examined are located in the U.S. National Museum (USNM) and the ichthyology collection of the Marine Laboratory, University of Miami (UM).

Key to the Species and Subspecies of *Stathmonotus*

A. Vomerine teeth present (Atlantic species)

B. Supraorbital, nuchal, and preopercular cirri present; posterior margin of tube of anterior nostril with a cirrus (*Auchenistius*)

C. Scales present; dorsal and anal fins confluent with caudal *S. stahli*

D. Articulated caudal rays 12, rarely 10 or 11 *S. stahli stahli*

DD. Articulated caudal rays 10 or 11, rarely 12 *S. stahli tekla*

CC. Scales absent; dorsal and anal fins scarcely or not confluent with caudal *S. gymnodermis*

BB. Supraorbital, nuchal, and preopercular cirri absent; posterior margin of tube of anterior nostril without a cirrus *S. (Stathmonotus) hemphilli*

AA. Vomerine teeth absent (Pacific species) (*Parastathmonotus*)

E. Supraorbital cirrus present

F. Cirrus present on posterior margin of tube of anterior nostril; dorsal spines 37-38; anal II, 20-22; depth 6.1-6.6 and head 4.5-4.7 in standard length *S. lugubris*

FF. No cirrus present on posterior margin of tube of anterior nostril; dorsal spines 40-45; anal spines II, 22-26; depth 7.1-9.9

and head 4.9-5.8 in standard length *S. sinus-californici*

EE. Supraorbital cirrus absent *S. culebrai*

Stathmonotus stahli (Evermann and Marsh)

Auchenistius stahli Evermann and Marsh, 1899: 359.

Stathmonotus tekla Nichols, 1910: 161 (here retained as a subspecies).

Histioclinus veliger Metzelaar, 1919: 157.

When specimens of this species are grouped geographically and a frequency distribution of the articulated caudal rays is made (Table II), it is seen that this species falls into two almost distinct groups for which names are available. At the present writing, insufficient specimens are available in order to reach a decisive conclusion as to the status of the groups, but it is felt that on the basis of past knowledge (Hubbs, 1952) of the susceptibility of the Clinidae to subspeciate, that the present interpretation will obtain. The ranges of the two subspecies, so far as known, are as follows: *S. stahli tekla* from Florida; Cay Sal Bank, Bahamas; Cuba; and Old Providence Island; *S. stahli stahli* from Puerto Rico; Virgin Islands; Martinique; and Bonaire.

TABLE 2.

FREQUENCY DISTRIBUTION OF THE ARTICULATED CAUDAL RAYS OF *Stathmonotus stahli*

Articulated caudal rays	10	11	12
S. stahli tekla			
Tortugas, Florida	1*	6	
Cay Sal Bank, Bahamas	1	3	
Cabañas Bay, Cuba		1	
Old Providence Island (off Nicaragua)		5	1
S. stahli stahli			
Bonaire (off Venezuela)			6
Puerto Rico			13**
Virgin Islands		1	2
Martinique	1		1

*Type of *S. stahli tekla*
**Includes type of *S. stahli stahli*

The following specimens were examined: 7 from Tortugas, Florida, USNM 116825, 116827, 116828, and 88114; 4 from Cay Sal Bank, Bahamas, UM 846; 1 from Cabañas Bay, Cuba, USNM

82549; 6 from Old Providence Island, USNM 107115 and 118165; 6 paratypes of *Histioclinus veliger* from Bonaire, USNM 160661; holotype of *Auchenistius stahli* from Ponce, Puerto Rico, USNM 49372; 8 paratypes of *A. stahli* from Culebra Island, Puerto Rico, USNM 126078; 1 from Cabo Rojo, Puerto Rico, USNM 128815; 3 from the Virgin Islands, USNM 120485 and 117440; and 2 from Martinique, USNM 117453. Information from the type of *S. tekla* is also included.

Stathmonotus gymnodermis new species

(Figure 2)

The holotype is an adult male 27.0 mm in standard length (USNM 117436), collected by the Smithsonian-Hartford Expedition from the vicinity of Fort San Gernonimo, San Juan, Puerto Rico, on March 28, 1937. Paratypes include: a ripe female 22.0 mm in standard length (USNM 163419), bearing the same data as the holotype; two specimens (USNM 163324), one a male 19.0 mm. in standard length and one sex indeterminate 13.0 mm in standard length collected by the Smithsonian-Hartford Expedition from the eastern shore of the harbor of St. Thomas, Virgin Islands, on April 4, 1937; and a female (USNM 163325) 18.2 mm in standard length, collected by the Smithsonian-Hartford Expedition from a coral reef in Christiansted Harbor, St. Croix, Virgin Islands, on April 8, 1937.

Measurements, given in thousandths of the standard length, and counts for the holotype are listed first, followed in parentheses, by those of the paratypes. In the case of the smallest paratype, no measurements are given.

Greatest length from tip of snout to membranous margin of opercle 204 (182, 205, 198). Least length from tip of snout to anterior bony margin of orbit 37 (36, 37, 38). Longitudinal bony diameter of orbit 37 (45, 47, 49). Least length from posterior margin of orbit to upper angle of opercle 111 (91, 100, 110). Tip of snout to origin of dorsal fin 189 (182, 184, 176). Tip of snout to point of greatest expansion of maxillary 82 (73, 84, 71). Greatest depth 148 (150, 116, 159). Least depth of caudal peduncle 67 (50, 53, 55). Origin of pelvic fin to origin of anal fin 322 (341, 337, 330). Origin of first dorsal spine to insertion of last dorsal spine 841 (823, 826, 819). Origin of first anal spine to insertion of last anal ray 452 (454, 474,

462). Longest pelvic ray 59 (59, 63, 60). Longest pectoral ray 74 (68, 79, 66). Longest caudal ray 118 (95, 110).

Dorsal spines 44 (44, 43, 42, 43) very gradually increasing in length (except at the 29th and 34th spines which appear to have been broken) to about fourth from last spine, then decreasing again. Dorsal free from caudal in type and one paratype, scarcely attached at base of caudal in other paratypes. Anal spines 2 in all specimens; anal rays 22 (21, 24, 25, 24), of about equal size. Anal beginning under 19th dorsal spine and ending at a point well in advance of caudal base. Caudal with 11 articulated rays in all specimens. Left pectoral rays 8 (8, 9, 9, 8); right pectoral rays 9 (8, 9, 8, 8). Pelvics I,2 and branchiostegals 6 in all specimens.

A tube on the anterior nostril with a simple cirrus on its posterior margin; a notched, paddle-shaped cirrus above each eye (one missing in one of the paratypes); a smaller cirrus on either side of nape. The preopercle covered by a membrane, visible externally only as a series of pores, one of which is bounded by a cirrus. In the two males the heads are somewhat swollen and the maxillaries and pectorals are somewhat longer than in the females.

Head and body scaleless; lateral line consisting of rudimentary pores, some double, the number of which cannot be distinguished with accuracy. Pores begin on head and continue in a straight line posteriorly to a point above the tip of the pectoral, then descending abruptly to the middle of the body and continuing almost to the base of the caudal.

Slightly recurved conical teeth on the premaxillaries and mandibles in two series anteriorly, merging into one posteriorly. Vomer with a single series of conical teeth. No teeth on palatines.

Anal opening with a papilla; opening in advance of origin of anal fin.

Color in alcohol is a uniform cream with dusky brown markings only on the supraorbital cirri.

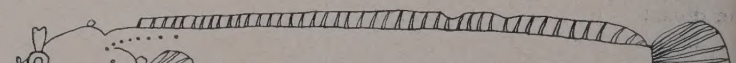

FIGURE 2. Holotype of *Stathmonotus gymnodermis*, 27.0 mm in standard length.

This species is most closely related to *S. stahli* from which it differs in the lack of scales, the more distinct separation of the vertical fins from the caudal, and the shorter pelvics. In four specimens of *S. stahli tekla* from Cay Sal Bank, the measurements of the pelvics in thousandths of the standard length were found to be 90, 94, 100, and 103. The caudal fin count of 11 for the new species is more or less out of the range (12, rarely 10 or 11) for specimens of *S. stahli stahli* with which it is sympatric.

Stathmonotus hemphilli Bean

Stathmonotus hemphilli Bean, 1885: 191.

Stathmonotus corallicola Beebe and Tee-Van, 1928: 249.

The type of *S. corallicola* was not seen, but there is nothing in the description of this species indicating that it differs from *S. hemphilli*. For this reason I place the two in synonymy.

Specimens from Miami, Tortugas, and St. Croix represent an extension of the range for this species which heretofore was known only from Key West, Port-au-Prince Bay, Bimini, and Antigua.

Comparative material studied is represented by the following: 1 from Long Reef off Miami, Florida, UM 899; 1 from Bimini, Bahamas, UM 41; 2 syntypes from Key West, Florida, USNM 37193; 2 from Tortugas, Florida, USNM 116808 and 116810; 6 from St. Croix, Virgin Islands, USNM 38775

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